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BOMBS

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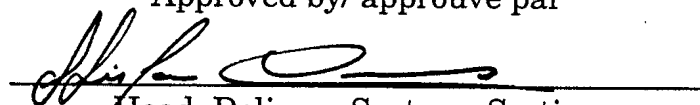
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ABSTRACT

Preliminary free - flight tests were conducted to verify the integrity of sabots and scaled models of the MK-82 CF, and full-scale MPB - HD (BDU-5003/B MOD 1) and MPB - LD (BDU-5002/B MOD 1) bombs launched from a powdered gun in the velocity range of 200 to 550 m/s. Two projectiles of each configuration were fired as well as a series of slugs for charge determination. The propellant charge mass, muzzle velocity, maximum accelerations, chamber pressure and drag coefficient were determined for each shot when fired from a 110-mm smooth bore gun with a high-low pressure chamber adapter. The models launched at a muzzle velocity less than 375 m/s were fired successfully.

RÉSUMÉ

Les essais préliminaires ont été effectués pour vérifier le bon fonctionnement des concepts de sabots et de modèles de bombe à échelle réduite pour le MK-82 CF, et à échelle réelle pour le MPB - HD (BDU-5003/B MOD 1) et le MPB - LD (BDU-5002/B MOD 1) tirés d'un canon à poudre dans la gamme de vitesses situées entre 200 et 550 m/s. Deux projectiles de chaque configuration ont été tirés ainsi qu'une série de balles noyaux pour déterminer les charges propulsives. La charge propulsive, les vitesses à la bouche du canon, les accélérations maxima, les pressions dans la chambre du canon et les coefficients de traînée ont été déterminés pour chaque tir d'un canon de 110 mm avec un adaptateur de pression haute-basse situé dans la chambre du canon. Les projectiles tirés à des vitesses à la bouche du canon à moins de 375 m/s ont bien fonctionné.

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EXECUTIVE SUMMARY

The CF has developed a Store Separation Model (SSM) to predict the separation of stores from the CF-18 aircraft given a configuration and initial conditions. This model was developed in order to reduce the risks of flight test incidents, and to reduce store separation work by directing efforts to critical areas. SSM has been used extensively by Canadair on behalf of DND to support various CF-18 stores clearance projects in the past. The existing flight matching technique uses a trial and error approach, which is very time-consuming and costly. It was shown recently that the implementation of the Maximum Likelihood Method (MLM) in the SSM could resolve its inherent deficiencies. The MLM has the capability of extracting aerodynamic coefficients and interference parameters, simultaneously from measured store separation trajectories. The Ballistic SSM (BSSM), under development, would be able to predict full-scale separation and ballistic flight test data for the CF-18 aircraft.

Even though the MLM is a well-proven technique to extract interference coefficients and aerodynamic coefficients (static and dynamic), the store separation tests usually do not have enough angular and translational motion so that it can be utilized to its maximum efficiency. It is therefore required to have a very good free stream aerodynamic (static and dynamic) coefficient data base of stores dropped from the CF-18 to be able to extract the interference coefficients with a high degree of confidence. If the free stream aerodynamics of the store are in error, the MLM will over or under estimate the interference coefficients to fit the overall observed motion. This reliable free stream aerodynamic data base will also be used with the BSSM to predict accurate store impact at the target and in the CF-18 Ballistic Integrator Algorithm.

DREV has a unique free - flight aeroballistic range where aerodynamic coefficients (static and dynamic) are reduced from measured trajectories with the MLM methodology. Projectiles (scaled or full scale) are fired from a powdered gun through 54 indirect shadowgraph stations. This aeroballistic range has shown over the years to be able to extract very reliable aerodynamic coefficients.

DREV was tasked by NDHQ to fire a first series of store configurations in the DREV aeroballistic range with the goal of obtaining their free stream static and dynamic aerodynamic coefficients. The stores that were chosen for this first phase were: MK-82 CF, BDU-5002/B Mod 1 (Modular Practice Bomb - Low Drag), and BDU-5003/B MOD 1 (Modular Practice Bomb - High Drag). The Mach number range of interest is between Mach 0.6 and 1.5.

This memorandum presents the projectile and sabot designs as well as the preliminary free-flight trials that are required prior to the aeroballistic range firings. The intents of these trials were to conduct a charge determination, to verify the model-sabot integrity at launch and the projectile stability of the models so as not to damage the aeroballistic range instrumentation. All projectiles were fired from a 110 mm smooth bore gun with a Hi-Lo adapter. The propellant charge mass, muzzle velocity, maximum acceleration, chamber pressure and drag coefficient were determined for each shot.

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NOMENCLATURE

C_D	drag coefficient
d	cylindrical diameter of models (mm)
I_X, I_Y	axial and transverse moments of inertia (g - cm ²)
l	length (m)
m	mass (g)
M	Mach number
MPB - HD	Modular Practice Bomb - High Drag
MPB - LD	Modular Practice Bomb - Low Drag

1.0 INTRODUCTION

The CF has developed a Store Separation Model (SSM) to predict the separation of stores from the CF-18 aircraft given a configuration and initial conditions in order to reduce the risks of flight test incidents, and to reduce store separation work by directing efforts to critical areas. SSM has been used extensively by Canadair on behalf of DND to support various CF-18 stores clearance projects in the past. Because of inherent model limitations, it is essential to implement the capability to adjust aerodynamic coefficients from the SSM database to match model predictions with flight test data. The existing flight matching technique uses an ineffective trial and error approach, which is very time-consuming and costly.

The Defense Research Establishment Valcartier (DREV) has successfully implemented a computerized system which uses the Maximum Likelihood Method (MLM) to iteratively extract aerodynamic coefficients and interference parameters, simultaneously, from the trajectory of test articles in their aeroballistic range and open jet facility. The heart of this system are two computer programs known as the BALListic Range Data Analysis System (BARDAS, Ref. 1) and Open Jet Facility Data Analysis System (OJFDAS, Ref. 2). OJFDAS, (Ref. 2), successfully showed that it was possible to extract store separation interference coefficients and free stream aerodynamic coefficients (static and dynamic), simultaneously. Feasibility work, which confirmed the compatibility of the MLM algorithms with the SSM, was carried out under MLM Phase 1 efforts (Ref. 3).

A SSM and Ballistic Store Separation Model (BSSM) compatible MLM algorithm, known as the Store Separation Model Data Analysis System (SSMDAS), was tested, under Phase 1 (Ref. 3) efforts and confirmed the ability of MLM techniques to correctly adjust aerodynamic free stream and

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interference coefficients to match SSM/BSSM predictions to full-scale separation and ballistic flight test data for the CF-18 aircraft. Implementation of such an automated system will improve the accuracy and efficiency of DND's SSM and BSSM for future store separation and ballistics work. Canadair was tasked to implement the MLM in the SSM and BSSM. The modified SSM and BSSM shall have the capability of using MLM techniques to achieve a match of SSM/BSSM predicted trajectories to actual observed separation and free - flight trajectory data of stores dropped from CF-18 aircraft during flight test.

Even though the MLM is a well-proven technique to extract interference coefficients and aerodynamic coefficients (static and dynamic), the store separation tests usually do not have enough angular and translational motion so that it can be utilized to its maximum efficiency. It is therefore required to have a very good free stream aerodynamic (static and dynamic) coefficient data base of stores dropped from the CF-18 to be able to extract the interference coefficients with a high degree of confidence. If the free stream aerodynamics of the store are in error, the MLM will over compensate for this, which might lead to errors in the determined interference coefficients. This reliable free stream aerodynamic data base will also be used with the BSSM to predict accurate store impact at the target and in the CF-18 Ballistic Integrator Algorithm. An NRC report (Ref. 4) also states this requirement for a reliable aerodynamic data base: "In this component approach to store integration, the essential baseline information is the store free stream aerodynamics. The aircraft flow field, carriage loads, and launch characteristics are considered as interferences (not necessarily small) to the aerodynamic characteristic of the store. Hence, whether flight tests, ground tests, or computations are used, a well-established aerodynamic data base for the store itself should be obtained".

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DREV has a unique free - flight aeroballistic range (Ref. 5 and 6) where absolute aerodynamic coefficients (static and dynamic) are readily obtainable from measured trajectories with the MLM methodology. Scaled or full-scale projectiles can be fired from a powdered gun through 54 indirect shadowgraph stations. This aeroballistic range has shown over the years to be able to extract very reliable aerodynamic coefficients.

DREV was tasked by NDHQ to fire a first series of store configurations in the DREV aeroballistic range with the goal of obtaining their free stream static and dynamic aerodynamic coefficients. The stores that were chosen for this first phase were: a scaled MK-82 CF (19%), a full-scale BDU-5002/B Mod 1 (Modular Practice Bomb - Low Drag, MPB - LD) and the BDU-5003/B Mod 1 (Modular Practice Bomb - High Drag, MPB - HD). The Mach number range of interest is between Mach 0.6 and 1.5.

This memorandum presents the projectile and sabot designs and the preliminary free - flight trials that are required prior to tests in the aeroballistic range. The goals of these trials were to conduct a charge determination tests to obtain the required Mach numbers and to verify the model-sabot integrity at launch as well as the projectile stability over 150 m so as not to damage the aeroballistic range instrumentation. All projectiles were fired from a 110 mm smooth bore gun with a Hi - Lo (High pressure - Low pressure) adapter. The propellant charge mass, muzzle velocity, maximum acceleration, chamber pressure and drag coefficient were determined for each shot.

This work was performed at DREV in June 1997, under Work Unit 3ec16, Improvement to CF-18 Ballistics Algorithms.

2.0 MODEL CONFIGURATIONS

Three aircraft store configurations were chosen as a first step in elaborating a free stream aerodynamic data base of various stores in the CF inventory. These are: the MK-82 CF, the BDU-5002/B Mod 1 (Modular Practice Bomb - Low Drag, MPB - LD) and the BDU-5003/B Mod 1 (Modular Practice Bomb - High Drag, MPB - HD).

The two MPBs were chosen since their caliber (50.8 mm) are an appropriate size to fire in the DREV aeroballistic range and that they are full scale. Also, an extensive wind tunnel data base exists at DREV on these two configurations and they were also tested at length from aircraft. These were also the configurations that were tested in the DREV open jet facility and used as a basis to validate the MLM methodology in obtaining store interference coefficients and free stream aerodynamic coefficients, simultaneously (Ref. 2).

The MK-82 500 lb low drag general purpose bomb was chosen as a third configuration since most of the validation and feasibility of using the MLM in the SSM was conducted from this store dropped from the CF-18 and that there was a high interest in obtaining free stream aerodynamic coefficients to as high as Mach 1.5 for operational use. This store is also in the SSM data base and it would be an ideal opportunity to verify its free stream aerodynamic coefficients and expand it to the higher Mach numbers. The model to be fired in the aeroballistic range has to be of course a scaled model.

2.1 MK-82 CF Configuration

The configuration for the MK-82 was scaled down to the same diameter as the MPB bombs, that is a nominal diameter of 50.8 mm. This implies that the model is a 18.6% scale model. This diameter was also chosen in order to basically have the same sabot design for all the projectiles. This saved design as well as manufacturing costs.

With guidance from NDHQ, the exact configuration that was modeled was obtained from various drawings supplied by NDHQ and these are:

- a. Drawing No. 1380544 - Bomb Assembly for MK-82 Mod and 3, General Purpose, 500 lb.
- b. Drawing No. 1380512 - Fin Assembly, conical, bomb, MK-82, General Purpose, 500 lb.
- c. Fin - Mau-93 Tail fin
- d. Lugs - MS3314 Suspension Lugs
- e. Nose Plug - Continue Ogive shape to a point

The configuration without the heat blanket was used. The surface imperfections of the real bomb (rivets, screws, etc.) were not retained for the scaled model.

From all of the above drawings and guidance from NDHQ, the geometry of the MK-82 that was retained for the free - flight tests is shown in Fig. 1. The dimensions are given in caliber and the reference diameter is 50.8 mm. The detailed drawings are given in Appendix A. Special care to the design of the model was taken to keep the center of gravity at the same position of the full-scale bomb.

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The general dimensions of the bomb are given in Fig. 1a. Two holes were drilled in line with a pair of fins to be able to launch the projectile with the sabot design (next section). The nominal center of gravity of the projectiles was situated at 3.71 cal from the nose of the projectile. The suspension lugs were located at 45° from a fin. The total length of the projectile is 8.57 cal.

The detailed dimensions of the tail section as well as the fins are shown in Fig. 1b. The fin profile was slightly simplified from the complex fin shape of the full scale bomb. This was done to reduce the manufacturing costs and it is not believed that this will have a major influence on the aerodynamic coefficients. The thickness of the fin was basically kept the same and the angle of cant was retained.

The ogive detail dimensions are provided in Fig. 1c. As mentioned previously, a pointed nose plug was used.

The placements of the suspension lugs and their dimensions were also scaled down and the details are supplied in Fig. 1d. Two small holes of 0.16 cal x 0.16 cal were drilled at 4.87 cal from the base of the projectile so as to be able to fire the scaled model from a sabot. It is not believed that this will affect the aerodynamic performance of the projectile, but special attention for possible shock waves emanating from the holes will be kept when conducting the aeroballistic range tests.

Photographs of the scale MK-82 are shown in Fig. 2. A general view is shown in Fig. 2a. The lug locations as well as the holes are easily seen. An expanded view of the fins is shown in Fig. 2b. A roll pin was added to one of the fins so as to be able to measure the roll orientation of the projectile when conducting tests in the aeroballistic range. The roll pin is placed on the fin

situated at -45° from the lug location when viewed from the rear. Figure 2c shows a detailed photograph of the lugs and the holes.

2.2 Modular Practice Bomb - Low Drag Configuration

The in service MPB - LD configuration was used. The main dimensions are provided in Fig. 3 in caliber. The reference diameter is 50.8 mm. The only external geometry difference from the standard practice bomb is that the fins were rotated 45° from the locator holes, i.e. one pair of fins is in line with the locator holes. This was done so as to be able to launch them with the sabot that was designed. The fumer cartridge was also replaced by a dummy one (see Appendix A) to keep the center of gravity and the mass as close as possible to the in service bomb.

The MPB - LD has a 1.35 cal ogive nose followed by a 4.07 cal cylindrical portion and the fins are placed at the end of an extended boattail. The fins have a 2.00 cal span and are of a clipped delta type. The center of gravity of the tested projectiles was located at 3.94 caliber from the nose with the dummy cartridge in the projectile. The total length of the projectile is 8.52 cal.

2.3 Modular Practice Bomb - High Drag Configuration

The main dimensions of the MPB - HD configuration can be found in Fig. 4 in caliber. Once more, the reference diameter is 50.8 mm. As with the MPB - LD configuration, the fins were rotated 45° from the locator holes and a dummy cartridge was placed inside the bomb.

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The MPB - HD has the same fin and body dimensions as the LD version. A high drag 0.07 cal thick retardation disk with a diameter of 1.76 cal is located at 1.89 cal from the nose. A 1.7 cal diameter high drag conical tail is placed just aft of the fins. The fin type and main dimensions are the same as the low drag version. The center of gravity, with the dummy cartridge in the test model, was approximately at 3.97 cal from the nose. The total length of the projectile is 8.55 cal.

2.4 Slugs

Slugs were also designed to be able to conduct a charge determination to obtain the desired muzzle velocities. These basically consisted of a 110 mm polycarbonate external cylindrical shell with a mild steel internal ballast mass. The aft end of the shell has a short 5° conical expansion. The mass of the slugs were approximately 4.50 kg which was roughly equivalent to the total sabot-projectile masses that were tested. The detailed drawings are provided in Annex A. A photograph of the slug is shown in Fig. 5.

3.0 SABOT DESIGN

Since the subcaliber projectiles have to be launched from a powdered gun to conduct tests in the DREV aeroballistic range, special sabots have to be designed to fire them. Since all the model configurations in this case are fin stabilized, a smooth bore gun was utilized. The standard gun employed at DREV to fire fin stabilized projectiles of these dimensions in the aeroballistic range is a 110-mm smooth bore gun.

Several aspects have to be considered when designing sabots and models. They are: projectile configuration, total mass, sabot separation at the sabot trap located at 9.2 m from the muzzle at the aeroballistic range, muzzle velocity desired, gun accelerations, etc. The last three mentioned have to be consistent from round to round. In these tests, the highest muzzle velocity desired was approximately 510 m/s (Mach 1.5) and the lowest, 200 m/s (Mach 0.6).

The tail portion of the modular practice bombs is made of a polycarbonate material. Therefore, it is impossible to launch them with a base plate pusher sabot since the projectile would disintegrate at launch. The modular practice bombs have two locator holes situated close to the center of gravity (Figs. 3 and 4) and a sabot design that would pull the projectile by these holes presented an interesting option.

Also, the base area of the MK-82 (Fig. 1) projectile was also too small to be able to launch them with a classical pusher type sabot. The launch loads at the highest muzzle velocities would have caused structural failure in that area. It was decided to launch them as the MPB projectiles by drilling two holes and use the same launching techniques as the MPBs. This option saved design as well as manufacturing costs.

3.1 MPB Sabot Design

In the late 1980s, DREV made an attempt to fire both modular practice bombs from a smooth bore gun with a pull type sabot design. The sabot functioned well for the low drag version but had inadequate separation for the high drag one. The muzzle velocities, at the same propellant charge

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mass, were also not consistent from round to round, for both projectiles. The designs presented here are a modification of the previously tested ones.

Figure 6 shows a schematic of the sabot for the MPB - HD configuration. The detail drawings of the sabot are provided in Appendix A. It is a two petal sabot design made of aluminum. The lengths of the saw cuts on each side were adjusted to obtain adequate petal separation for the expected velocities. A sabot base seal pad was also used to prevent gas leakage past the sabot body. It has two pins at the front of the sabot to pull the projectile down the barrel. These pins were designed to fit the in service MPB locator holes.

A pivot pin, which is in line with the saw cuts, was added to force the sabot opening at that point. A polycarbonate ring with a 5° angle is positioned at the aft end of the sabot. There are two reasons for this. The first one, is to have a good pressure seal between the sabot and the gun tube so as to be able to have a known shot start pressure which helps in having consistent muzzle velocities at the same propellant charge mass. The second reason is that, as the sabot leaves the gun tube, the high radial pressure acting on the rear ring relative to the front part, causes the pivoting action at the pivot point of the sabot petals.

In the earlier sabot design (1988), the petal opening functioned only with ram air (no pivot pin) passing through the sabot and forcing the petals to open by air pressure only. For the MPB - HD version, the sabot petal separation was not adequate since the high drag disk deviated to much ram air from inside the sabot. It was hoped that the new design, with the pivot pin and conical forcing ring would solve the earlier problems, that is, the sabot opening and consistent muzzle velocities.

A photograph of the sabot-model package as well as all the components is shown in Fig. 7. One should notice the roll pin placed on one of the model fins to permit calculating the roll orientation of the projectile when fired in the aeroballistic range. The total model-sabot mass is approximately 5.1 kg.

The sabot for the MPB - LD version is exactly the same as the high drag one. A photograph showing this projectile with the sabot is given in Fig. 8. The total package mass was also about 5.1 kg.

3.2 MK-82 Sabot Design

The sabot design for the MK-82 scaled projectile is very similar to the MPB models. A sketch showing the general arrangement is given in Fig. 9 and the detail drawings are provided in Appendix A.

The base of the sabot was slightly modified to allow space for the portion of the projectile body aft of the fins to sit in. Also the pivot pin was slightly modified (Appendix A) to allow for a longer roll pin. All the other components of the sabot are basically the same.

A photograph showing the MK-82 projectile with the sabot is given in Fig. 10. The total sabot-projectile mass was about 4.9 kg

4.0 EXPERIMENTAL SITE AND INSTRUMENTATION

The integrity trials were conducted at a short (150 m) open range at DREV. A schematic of the test setup is shown in Fig. 11. A sabot trap was installed at approximately 9.2 m from the gun muzzle to duplicate the launch configuration at the aeroballistic range. This is particularly important for the sabot petal separation. Two high-speed photographic stations were positioned fore and aft (8.2 m and 10.2 m from the gun muzzle) of the sabot trap to photograph the sabot separation and model integrity. A cardboard target was situated at 150 m from the muzzle. All the projectiles were fired from a 110-mm smooth bore gun.

Two radars were utilized for these tests. One to obtain the acceleration of the sabot-model package inside the gun tube and a second to obtain the velocity history of the projectile in flight. The detail configuration and location of the radars are shown in Fig. 11. The acceleration in the gun tube was measured by a continuous Doppler type radar with a transmission frequency of 35 GHz. It was placed behind the gun and aimed at a metalized mylar radar signal reflecting mirror placed in front of the sabot trap. The mirror was located on the side of the firing line to avoid model disturbance or damage, and oriented towards and inside the gun muzzle. The data analysis was then conducted with an Fast Fourier Transform (FFT) analyzer to obtain the velocity and acceleration history inside the gun tube.

The projectile velocity was measured with a continuous Doppler radar with a frequency of 10.492 GHz. This radar was situated passed the sabot trap looking down range and 1.22 m below the line of fire. It was aimed 3 meters above the target so as to capture the model radar signal reflection as quickly as possible. The projectile's velocity history and its muzzle velocity were obtained from this radar. The signal processing was conducted with an

FFT analyzer. The drag coefficients were calculated from the velocity history after the FFT analysis with PC-Radar Assistant (Ref. 7).

The chamber pressures were measured with crusher gauges placed in the Hi - Lo adapter located in the gun chamber.

5.0 TEST CONDITIONS AND PARTICULARITIES

A total of twelve rounds were fired in these trials which consisted of 6 slugs for charge determination, and two of each projectile configuration of the MPB - HD, MPB - LD and MK-82. The physical properties of each test projectile are provided in Table I. The atmospheric conditions at the time of firing are given in Table II.

All the projectiles were fired with a sabot from a 110-mm smooth bore gun. A special Hi - Lo adapter (Fig. 12) was utilized in the gun chamber to obtain consistent gun pressures to propel the model-sabots at low repetitive muzzle velocities and to achieve the lowest launch accelerations as possible.

Since the muzzle velocities desired for these trials are quite low, a standard 105-mm cartridge would not be suitable. The propellant mass required in a standard cartridge would be too small to obtain adequate uniform burning of the propellant and would lead to inconsistent muzzle velocities. The Hi-Lo adapter fits in the chamber of the 110-mm gun to equalize the pressure in the gun tube.

The Hi-Lo adapter comprises several components (Fig. 12): an obturator, a diffuser, a joining shaft, a standard M63 primer, O-ring seals on the adapter and on the diffuser, and an end nut. For these trials, the 9.525

mm diffuser was utilized. Several other diffusers were available but not used in this trial. A propellant charge is placed around the shaft (High pressure section) between the obturator and the diffuser and it is ignited by the burning gases from the primer escaping the holes in the shaft. The pressure in the gun tube (Low pressure section) is controlled by the escaping gases through the nozzles of the diffuser. The complete drawings of the adapter can be found in Appendix B.

6.0 RESULTS AND DISCUSSIONS

The main objectives of the trials were to verify the sabot-model integrity and functioning over a speed regime between 200 and 500 m/s and to determine the charge required to obtain the required muzzle velocities. All the tests were conducted with the N-3-1-1 (0.035" web) propellant. This propellant was well suited to obtain the required muzzle velocities of interest with the Hi - Lo adapter.

The results of all the gun launches are given in Table III. The total sabot-projectile mass is provided. The chamber pressure presented is the average of two crusher gauges placed in the high pressure section of the Hi - Lo adapter. In some cases, the pressures were too low and could not be recorded (NR). The accelerations were measured with a radar looking down the barrel through a reflector and only the maxima achieved are reported.

The muzzle velocities from two methodologies for the radar looking down range are provided. The one labeled "DREV" was obtained by extrapolating the velocity history to time zero with a linear fit. Some judgment from the operator is required. The one labeled "PC Radar" (Ref. 7) was obtained by solving for the muzzle velocity (at time zero) using the

equations of motion. The third muzzle velocity is the one measured in bore. A typical velocity and acceleration history in the barrel is shown in Fig. 13 for Slug A1.

The muzzle velocities obtained from the external radar with the three methods are very consistent except for the MPB - LD configuration. The two shots (C4 and C5) had sabot structural failure. The reasons for this will be detailed in a section below. The muzzle velocities were consistent and repeatable for the same charge mass. The maximum accelerations ranged from 1000 gn at the lowest propellant charge mass to as high as 7 500 gn at the maximum charge that was tested.

6.1 Charge Determination

The first part of the trial consisted in doing a charge determination. This involved firing slugs at determined propellant charge masses and measuring the velocities. Only one slug mass was utilized for these tests. The charge-velocity graph is given Fig. 14. The charge mass is provided in both ounces and grams on the X scales and the muzzle velocity and the Mach number at the muzzle are furnished on the Y axes. The repeated shots are not clearly distinguishable since the velocities obtained at the same charge mass were very close. A third degree polynomial was fitted through the experimental data. This graph clearly shows that, for a slug mass of 4.5 kg, it is possible to obtain the muzzle velocities that were required for the aeroballistic range tests.

This graph is very useful in obtaining the required charge mass at muzzle velocities that were not tested. This was conducted for the projectiles and sabot tests. Even though the desired muzzle velocities can be achieved,

special attention has to be placed on the launch accelerations since the sabots and models were designed for a specific maximum acceleration. To obtain the highest muzzle velocity of 500 m/s, the launch accelerations were approximately 7 500 gn.

6.2 Sabot-Model Separation and Structural Integrity

The next series of tests that followed were intended to:

- a. verify if the sabots and models could survive the launch loads over the required speed regime,
- b. confirm adequate sabot separation at the sabot trap,
- c. assure that the projectiles have adequate stability to reach the target,
- d. obtain some drag coefficient data.

Two projectiles of each configuration were fired. The MK-82 and the MPB - HD were fired at a low and at an intermediate velocity while the MPB - LD was fired at the higher end of the speed spectrum. Unfortunately, there was sabot breakage at the higher charge mass when firing the MPB - LD projectiles. The reasons for this sabot structural failure are known and will be elaborated upon further below.

The muzzle velocities obtained for the projectiles are shown with the slug data in Fig. 15. The velocity data shown is from the "DREV" extrapolated data, except for the two sabot failures where the muzzle velocities of the in-bore data was used. The muzzle velocities obtained for the test projectiles follow quite well the slug data. This implies that the 5° ring utilized at the aft end of the sabot worked remarkably well in obtaining muzzle velocity consistency over the earlier sabot design.

The maximum accelerations achieved for all the tests are provided in Fig. 16. The solid line is the best linear fit with the slug data. The maximum acceleration attained is very linear with the charge mass and the data for the test projectiles fall exactly on the slug data, except for one of the two projectiles that suffered sabot structural failure.

It is quite evident from the acceleration data, that it would not be very prudent to fire any projectiles over 4 000 gn with this sabot design. This is equivalent to a muzzle velocity of 370 m/s, which is a little below the desired maximum.

Typical photographs of the sabot separation for the MK-82 at the two camera positions are shown in Figs. 17 and 18 (muzzle velocities of 251 and 375 m/s, respectively). As can be seen, the sabot separation was clean and the main sabot pieces were stopped by the sabot trap. Some minor pieces did follow through, but this is considered acceptable, as more protection is available at the entrance of the aeroballistic range. There is some slight yaw and the roll pins are visible.

Similar photographs for the MPB - HD projectiles can be seen in Figs. 19 and 20 at muzzle velocities of 343 and 245 m/s, respectively. The sabot petals separated cleanly and there is ample yaw on projectile D1 as seen in the second camera position. This is ideal for aeroballistic range tests. The average sabot separation at the sabot trap for these four shots was approximately 43 cm, which is quite adequate. Also, all the projectiles reached the target and all imprints indicated no damage to the projectiles.

Figure 21 shows photographs of the two MPB - LD projectiles that suffered sabot structural failure. The expected velocities for these two shots

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(Fig. 15) were 395 m/s (Mach 1.2) and 415 m/s (1.22) with respective maximum accelerations (Fig. 16) of 4000 and 4500 gn. After inspection of the recovered sabot petals and subsequent stress calculations, it was quite evident that the structural failure occurred at the junction where the pins pull the projectiles. The pins were also bent, but this was probably due to the sabot structural failure.

To resolve the structural problems, it was decided to increase the hardness of the pulling pins and to increase the amount of material in that area to make it more solid. It is believed that these modifications will resolve the structural failure that occurred. It was also decided that, for the aeroballistic range tests, only the MK-82 projectiles would be fired at the highest charges so as to obtain the aerodynamic characteristic of the projectile as close as possible to Mach 1.5.

These changes and other minor ones are given in the sabot drawings provided in Annex A. The modifications are indicated by the mention of "now" and "was".

6.3 Drag Coefficient

The opportunity was taken to evaluate a new software to calculate the total drag coefficient of the test projectiles from Doppler radar. The software is labeled "PC Radar - Assistant" (Ref. 7) and is a draft version. It first conducts sectional fits (depending on calibers of travel) with the four degree of freedom equations of motion and a global fit over the whole data set to obtain the final drag coefficient.

The reduced drag coefficient for the slugs are given in Fig. 22. These are compared with the data from Ref. 8. The six shots are shown with the same labeling. All the triangles represent individual shots, except for the four diagonal ones in the transonic region which is for one shot. At Mach 0.6 the radar drag coefficient is higher than the published data by approximately 33%. The radar drag coefficient of the three shots at Mach 1.05 and 1.25 agree quite well with the reference data. The four points in the transonic region are superior to the published data by about 22%.

The MPB - HD radar reduced drag coefficient is compared on Fig. 23 with wind tunnel data from DREV's indraft wind tunnel (Ref. 9). The data for two shots are provided, one at Mach 0.6 and another in the transonic region. The agreement with the published data is quite acceptable, especially in the region of Mach 0.9.

Figure 24 compares the drag coefficients obtained from the new software for the MK-82 with Ref. 10. Again only two shots were available for comparison. The same configuration is compared, that is the projectile with the conical fins and with lugs attached and with a similar nose plug. It should be mentioned that the projectiles of the reference were full-scale MK-82. The agreement with the published data is excellent. This provides ample

confidence that the slight modifications that were made on the fins of the free-flight scaled models for these tests as well as the lugs that were added and the fact that this is a 19% scale model does not influence the drag coefficient significantly.

7.0 CONCLUSIONS

The initial free - flight trials to test the sabot concepts to launch three bomb configurations were successfully completed. A series of slugs were fired from a 110-mm smooth bore with a special Hi - Lo adapter to determine the required propellant charges to fire the projectiles in a velocity range of 200 to 500 m/s. A total of six projectiles, two of each following configurations were fired: a 19% scaled MK-82 CF, a full-scale BDU-5002/B Mod 1 (Modular Practice Bomb - Low Drag) and the BDU-5003/B Mod 1 (Modular Practice Bomb - High Drag).

The maximum accelerations and the muzzle velocities were determined from the experiments as well as the drag coefficients with a new software package.

Some sabot failures occurred at the higher muzzle velocities and the reasons for this have been identified and solutions were brought forward.

The next step in the project is to fire the three different configurations in the DREV aeroballistic range to determine their aerodynamic characteristics and stability derivatives (static and dynamic) with the goal of establishing a reliable data base. It is planned to conduct these trials in the spring of 1998. This will then be used with the Ballistic Integrator Algorithm (BIA), SSM, BSSM and SSMDAS.

8.0 ACKNOWLEDGMENTS

The authors would like to thank the CEEM-V trials team for the successful completion of these tests. Capt. Dobrei of DTA is also thanked for his many inputs in the design of the scaled MK-82 configuration and Mr. E. Fournier for a literature search and his inputs in the design of the MK-82 scaled model.

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6. Dupuis, A. and Drouin, G., "The DREV Aeroballistic Range and Data Analysis System", AIAA Paper No. 88-2017, AIAA 15th Aerodynamic Testing Conference, San Diego, California, 18-20 May, 1988.
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9. Girard, B., Drouin, G. and Cheers, B., "Supersonic Wind Tunnel Tests (MPBWT-5) of the Modular Practice Bomb", DREV M-2662/84, June 1984, UNCLASSIFIED
10. Krishnamoorthy, L. V., "Drag Characteristics of Mk 82 General Purpose Low Drag Bomb as Derived From Full Scale Drops at Woomera Instrumented Range Facility", 22nd Meeting of TTCP WTP - 2, DREV, Canada, 12-15 May 1997.

TABLE I
Measured physical properties of test projectiles

Model Type	Model Number	Projectile Diameter (mm)	Projectile Mass (g)	l (mm)	I _x (g cm ²)	I _y (g cm ²)	CG from nose (%)
MK-82	B1	50.80	2 477.5	435.36	7 989.12	177 099.03	0.4329
	B2	50.80	2 477.6	435.40	7 982.77	176 923.05	0.4329
MPB - HD	D1	50.90	2 745.5	432.92	10 221.41	173 712.59	0.4661
	D2	50.83	2 715.5	433.55	10 265.24	169 161.73	0.4645
MPB - LD	C4	50.90	2 730.6	431.60	9 932.45	162 544.69	0.4642
	C5	50.72	2 691.5	431.95	9 604.06	158 840.82	0.4636

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TABLE II
Firing Conditions

Model Type	Model Number	Date Fired	Atmospheric Temperature (°C)	Atmospheric Pressure (kPa)
SLUG	A1	97-06-3	19.0	100.17
	A2	97-06-3	19.0	100.04
	A3	97-06-3	20.0	99.90
	A4	97-06-3	20.0	99.90
	A5	97-06-4	10.0	99.90
	A6	97-06-4	15.0	99.60
MK-82	B1	97-06-5	13.0	99.80
	B2	97-06-5	15.0	99.80
MPB - HD	D1	97-06-5	15.0	99.80
	D2	97-06-5	11.0	99.90
MPB - LD	C4	97-06-4	21.0	99.50
	C5	97-06-9	17.0	99.50

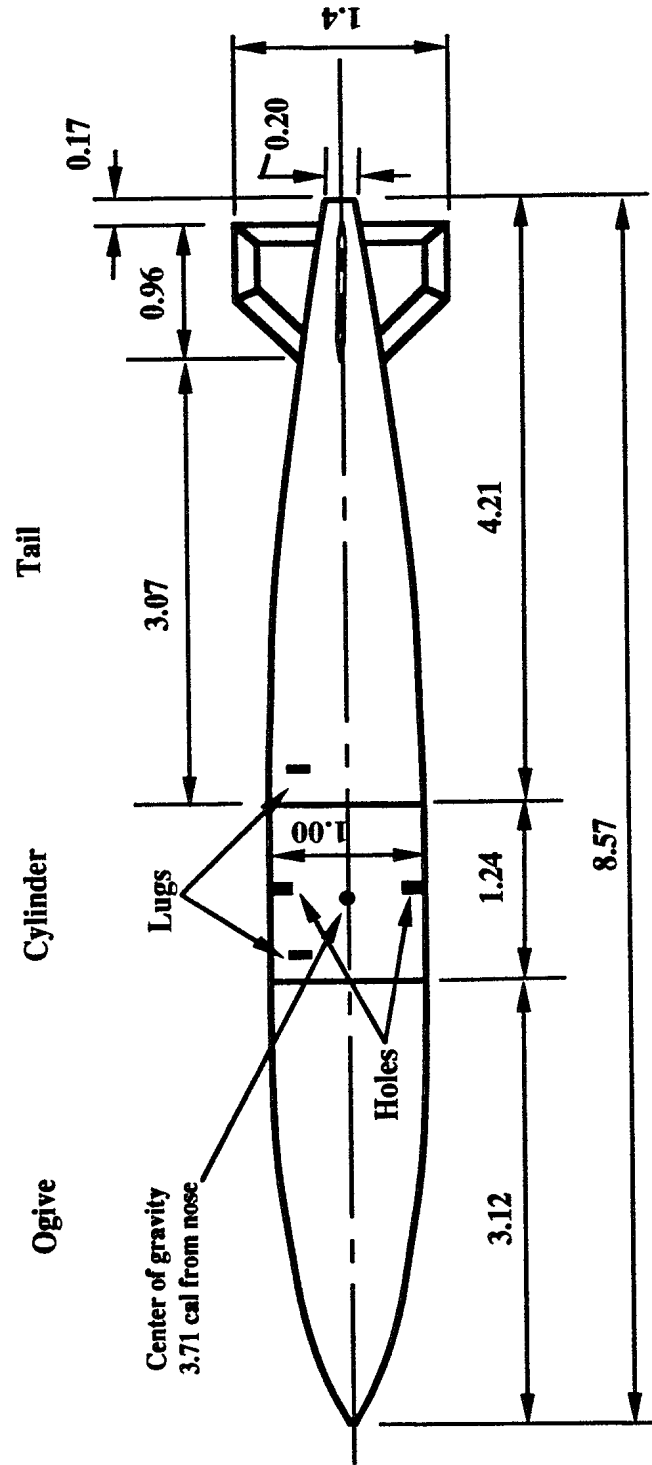
TABLE III
Results from gun firing with 110 mm gun with Hi-Lo adapter
(N-3-1-1 0.035" web, 9.525 mm diffuser)

Model Type	Model Number	Total Launch. Mass (kg)	Charge Mass		Chamber Pressure (MPa)	Maximum Acceleration (gn)	Muzzle Velocity (m/s)		In bore Muzzle Velocity (m/s)
			(g)	(oz)			DREV	PC Radar	
SLUG	A1		340.2	12.0	144.1	5282	447.9	448.7	446.7
	A2		340.2	12.0	130.3	5737	449.6	451.4	448.8
	A3	4.495	453.6	16.0	147.6	7437	504.5	503.6	502.7
	A4		85.1	3.0	NR	1075	213.8	214.5	211.5
	A5		85.1	3.0	NR	1041	213.5	214.5	211.4
	A6		212.6	7.5	59.63	3215	356.7	359.4	354.3
MK-82	B1	4.894	113.4	4.0	NR	1697	250.5	250.5	247.4
	B2		241.0	8.5	75.50	3778	374.6	375.7	369.6
MPB - HD	D1	5.087	212.6	7.5	58.61	3295	343.2	346.1	339.2
	D2		113.4	4.0	NR	1690	245.0	245.4	242.9
MPB - LD	C4*	5.100	283.5	10.0	98.25	4762	414.0**	-	384.9
	C5*		255.1	9.0	84.80	4930	376.2**	-	368.3

* Model-Sabot Breakage, NR - Not Recorded

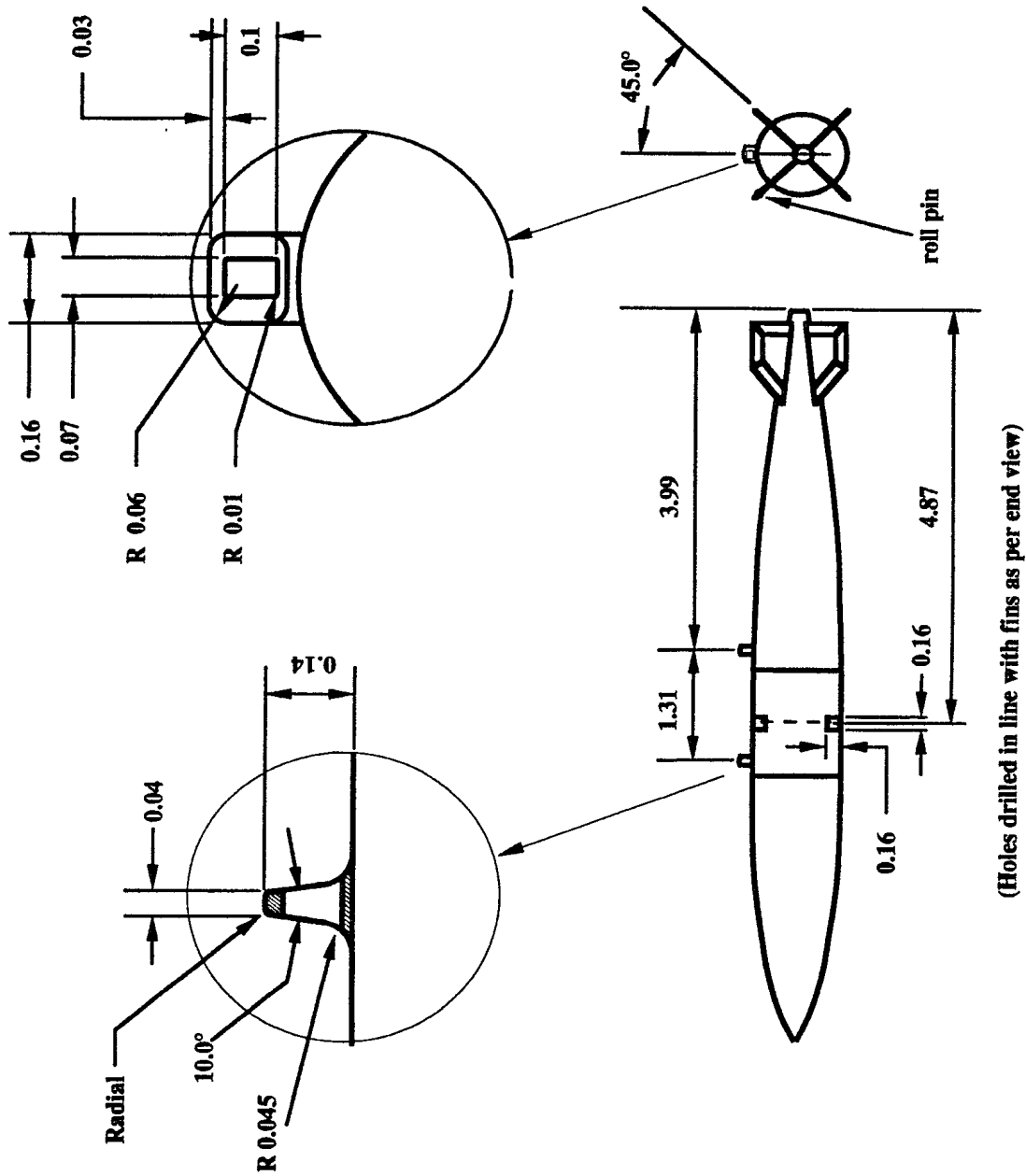
** Velocity obtained from maximum points on spectral analysis

FIGURE 1 - MK-82 geometry for aeroballistic range tests
(all dimensions in caliber)



a) General view

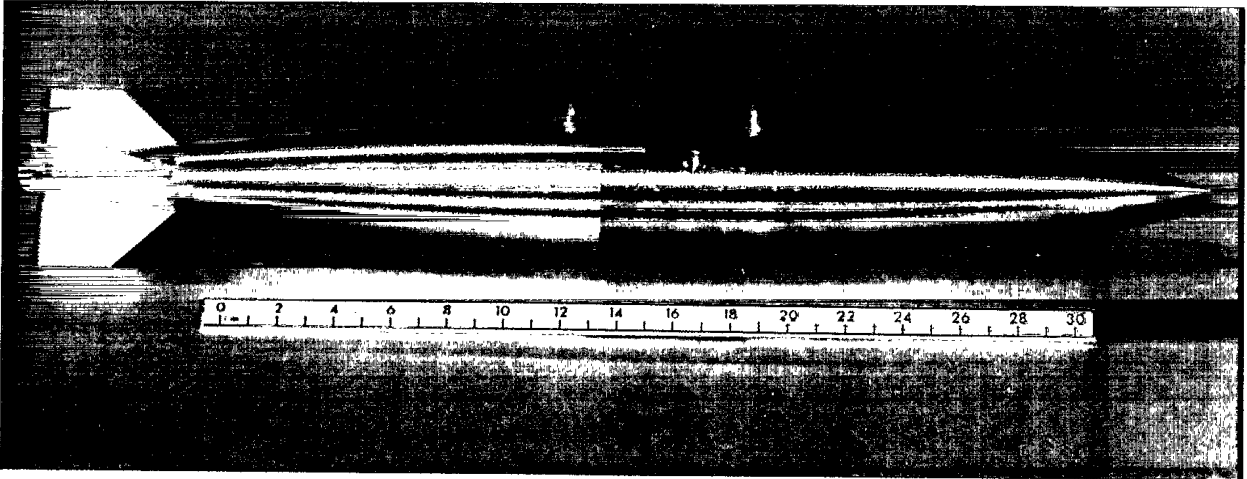
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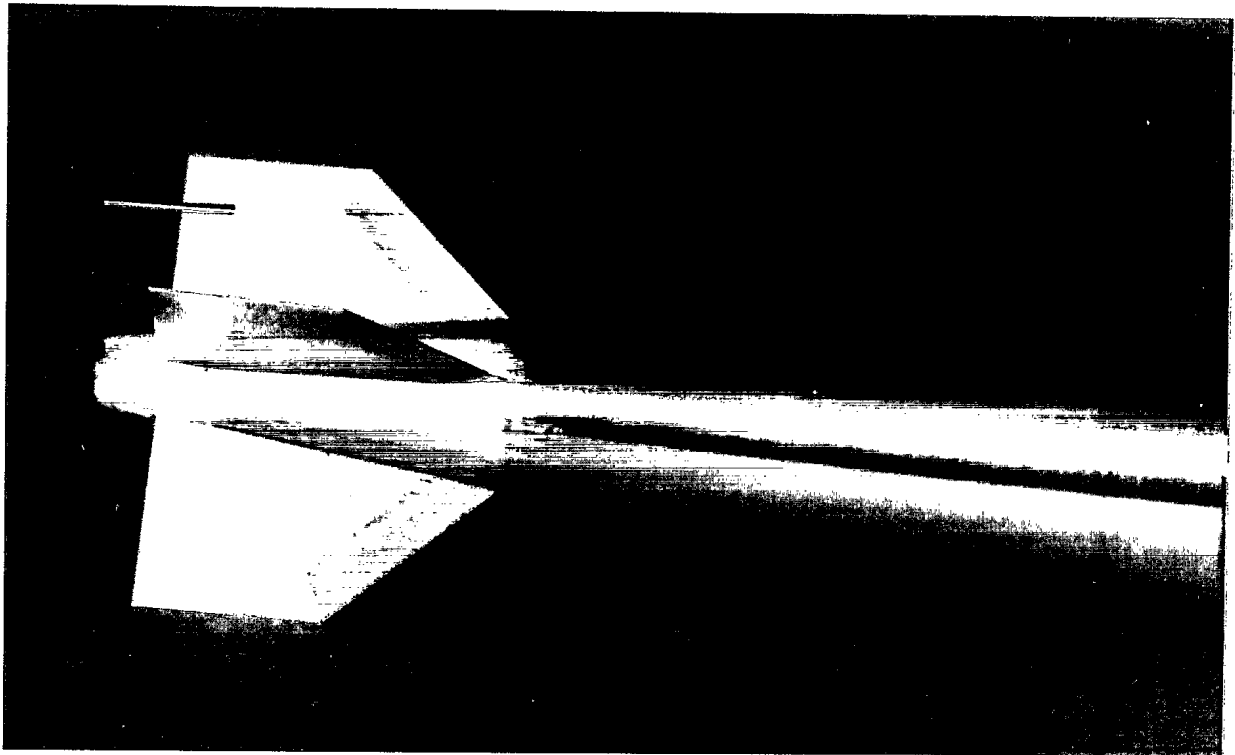
d) Suspension lugs and sabot pin holes details

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FIGURE 2- Photographs of scaled free-flight MK-82 projectile



a) General view



b) Fin detailed view

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c) Suspension lugs and hole view

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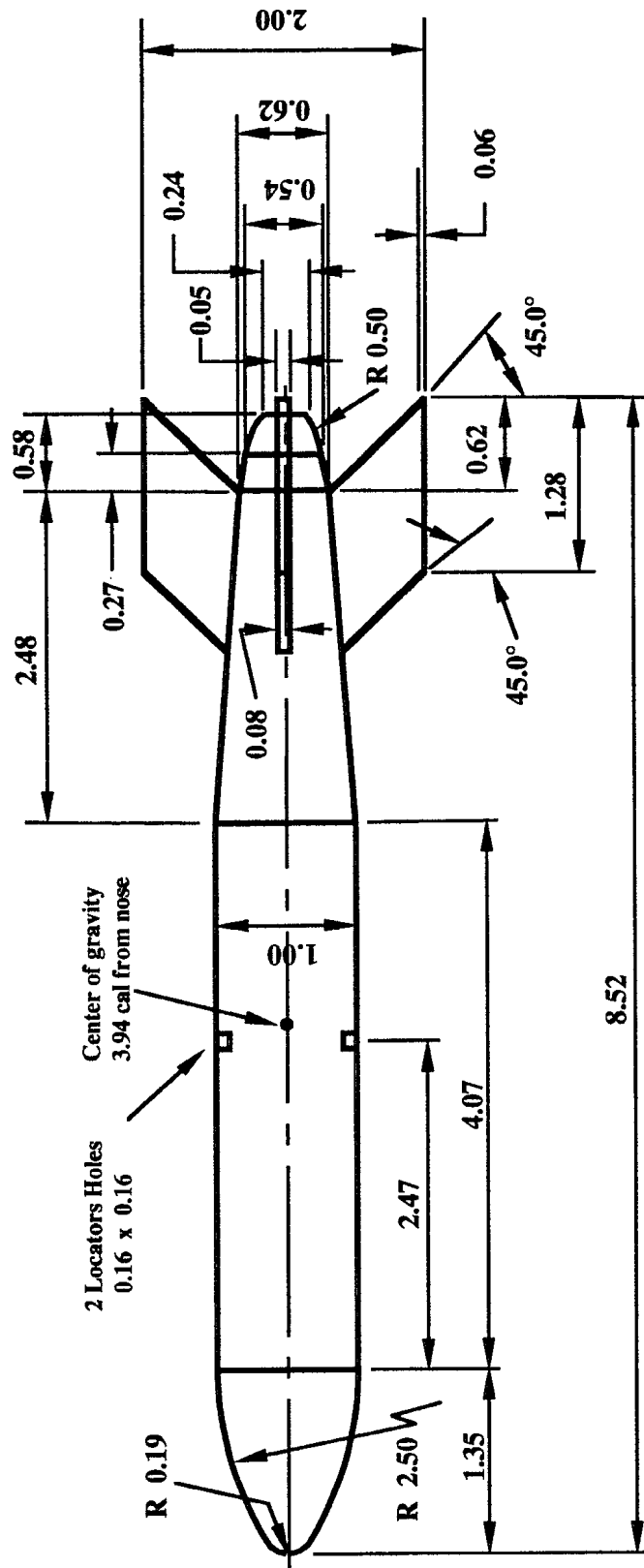


FIGURE 3 - MPB - LD configuration (all dimensions in caliber)

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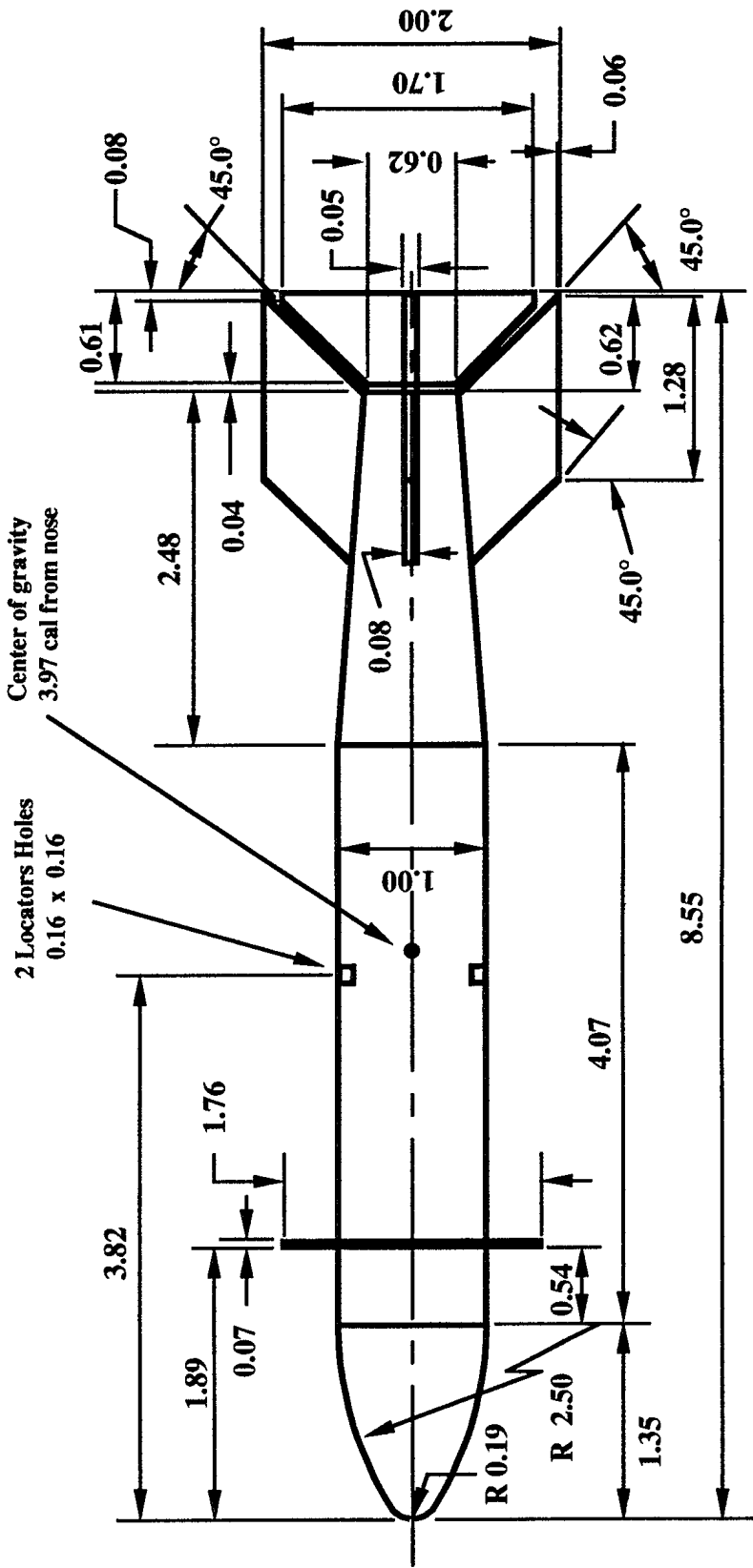


FIGURE 4 - MPB - HD configuration (all dimensions in caliber)

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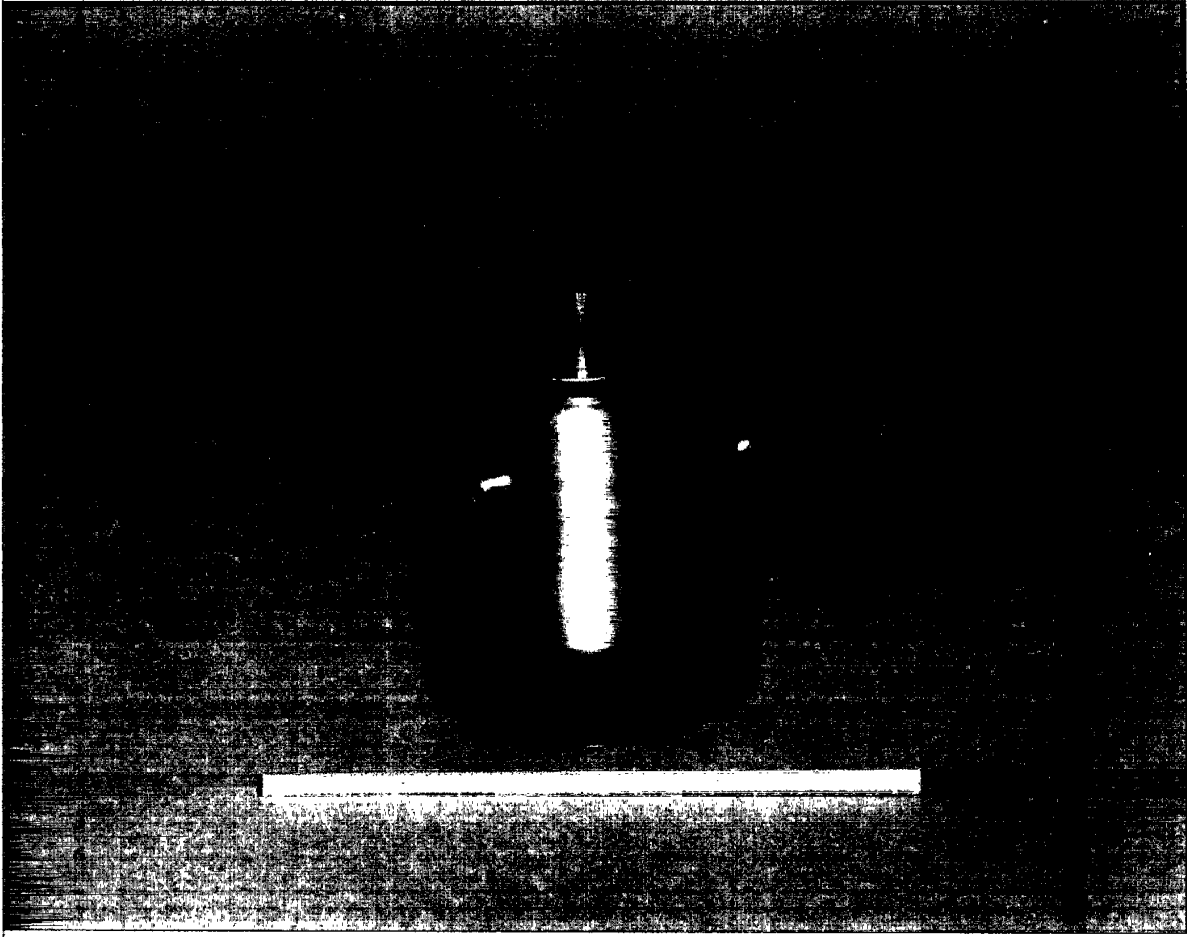


FIGURE 5 - Photograph of slug

FIGURE 6 - Sabot schematic for the MPB - HD projectile

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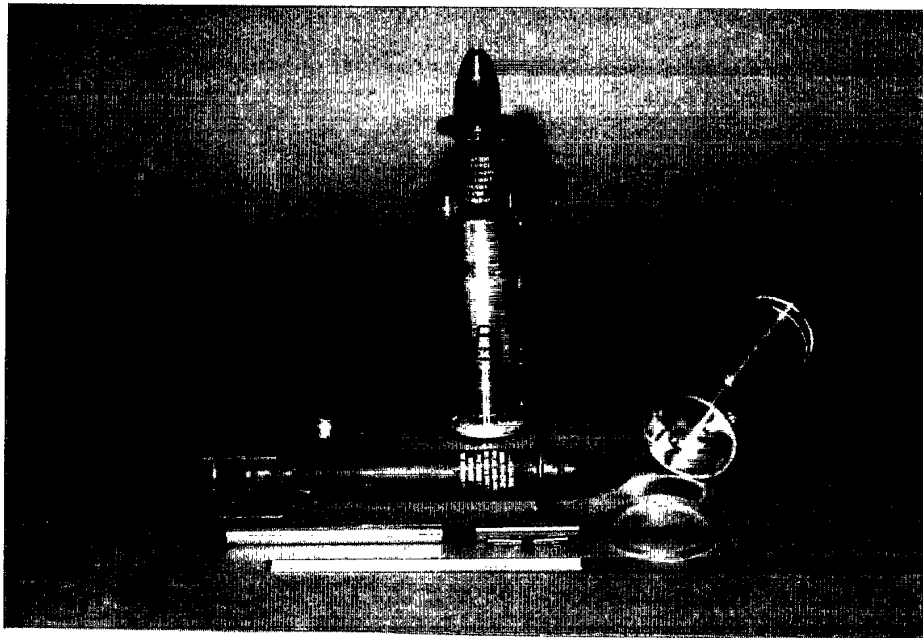


FIGURE 7 - Photograph of model and sabot package of MPB - HD configuration

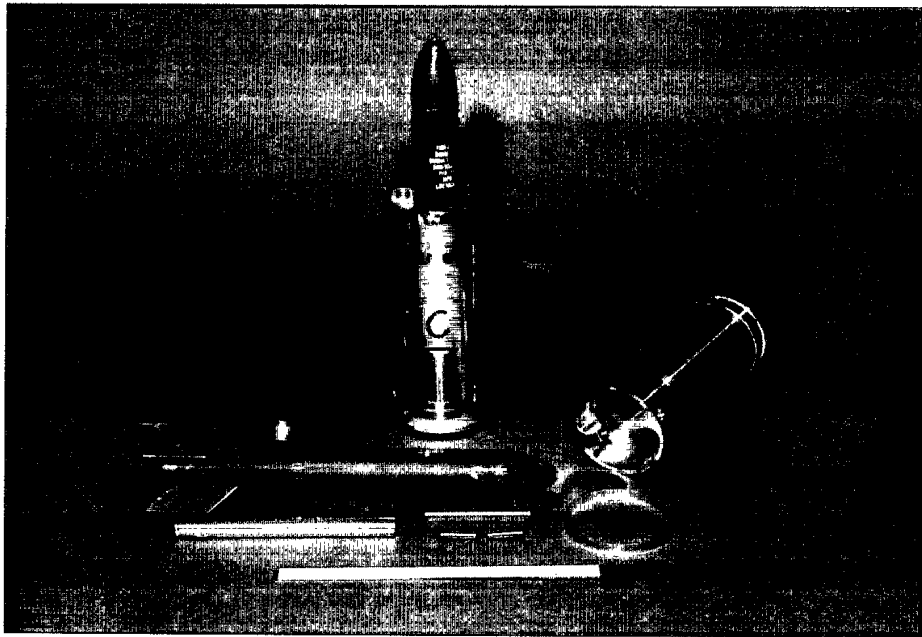


FIGURE 8 - Photograph of model and sabot package of MPB - LD configuration

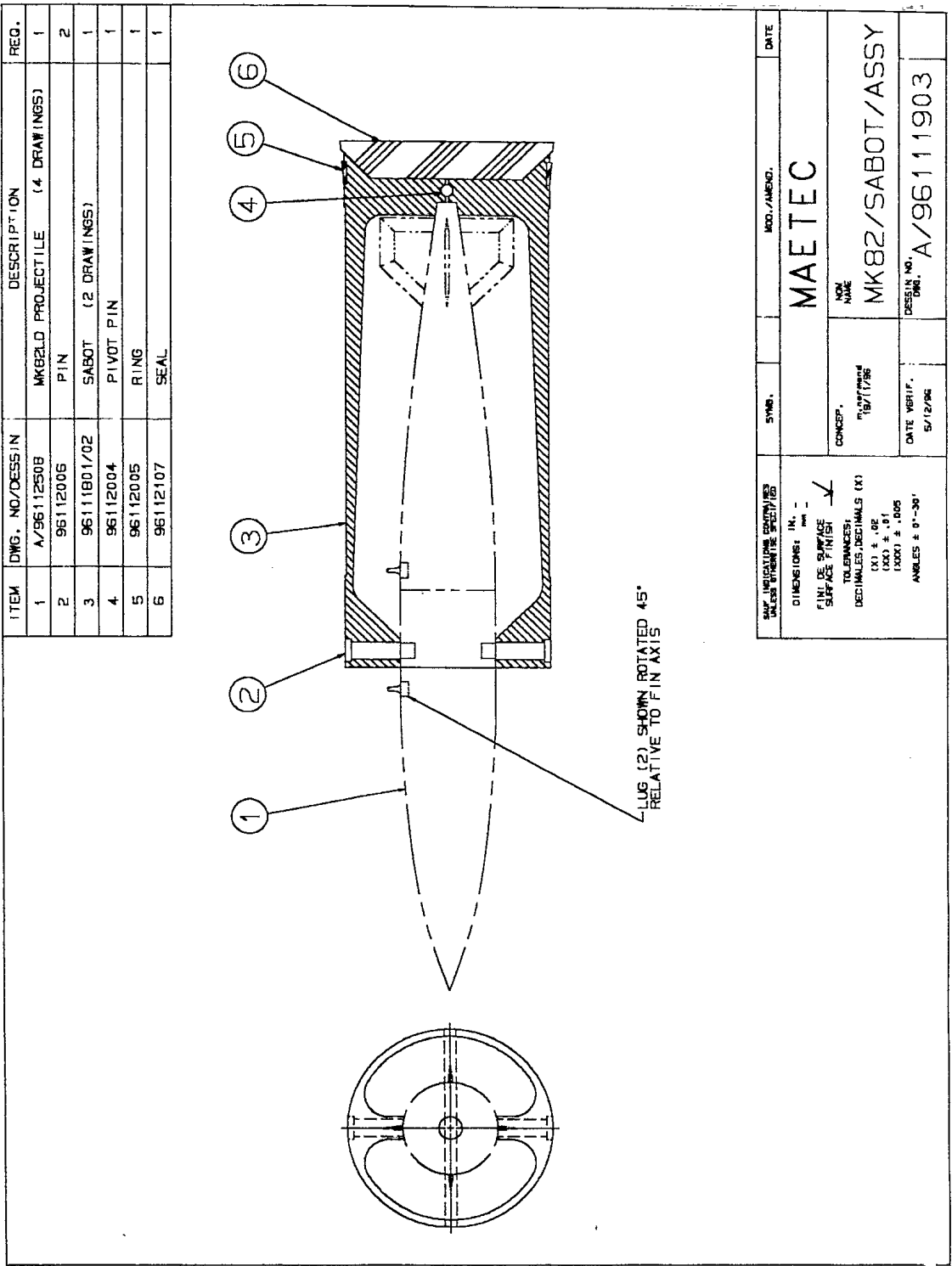


FIGURE 9 - Sabot schematic for the MK-82 scaled projectile

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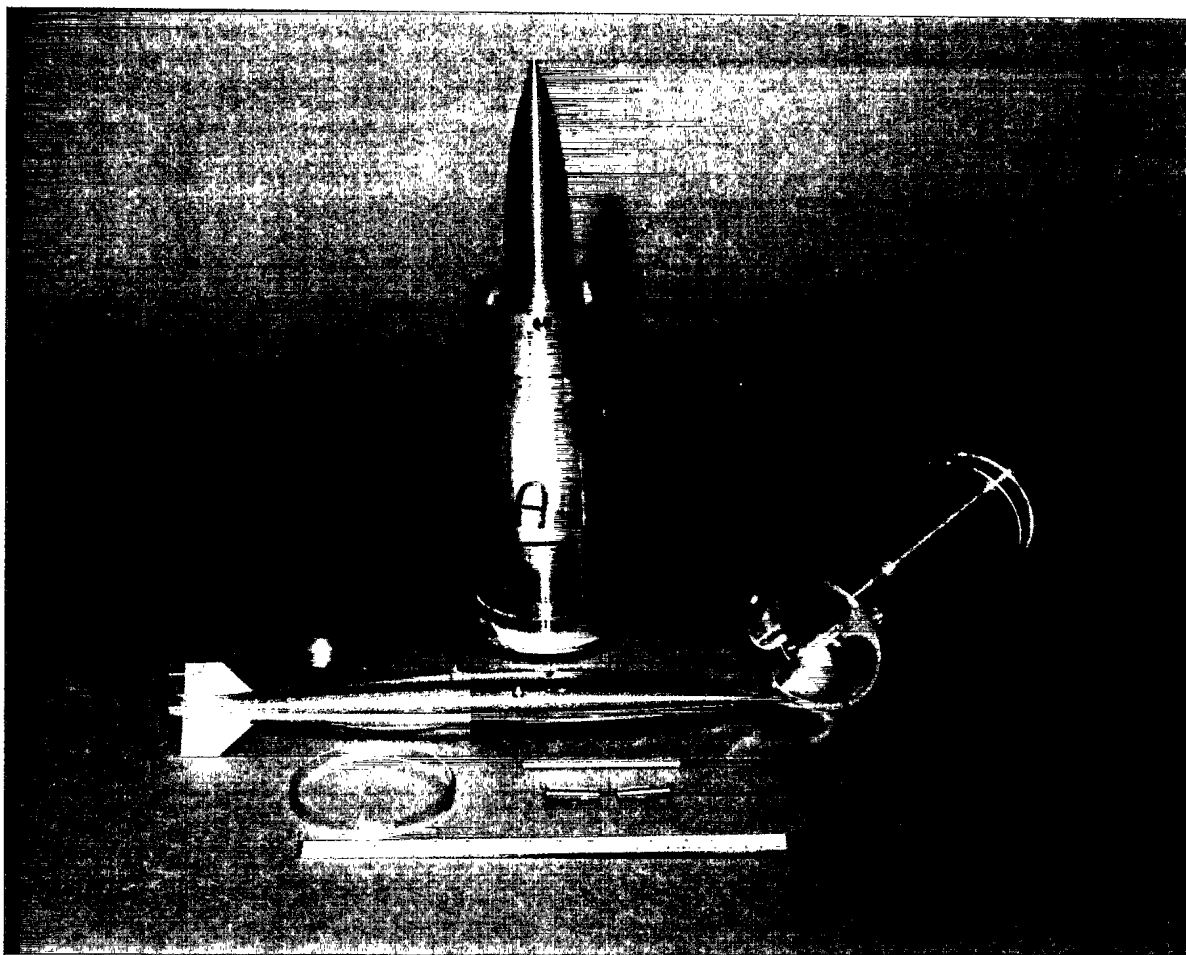


FIGURE 10 - Photograph of model and sabot package of MK-82 configuration

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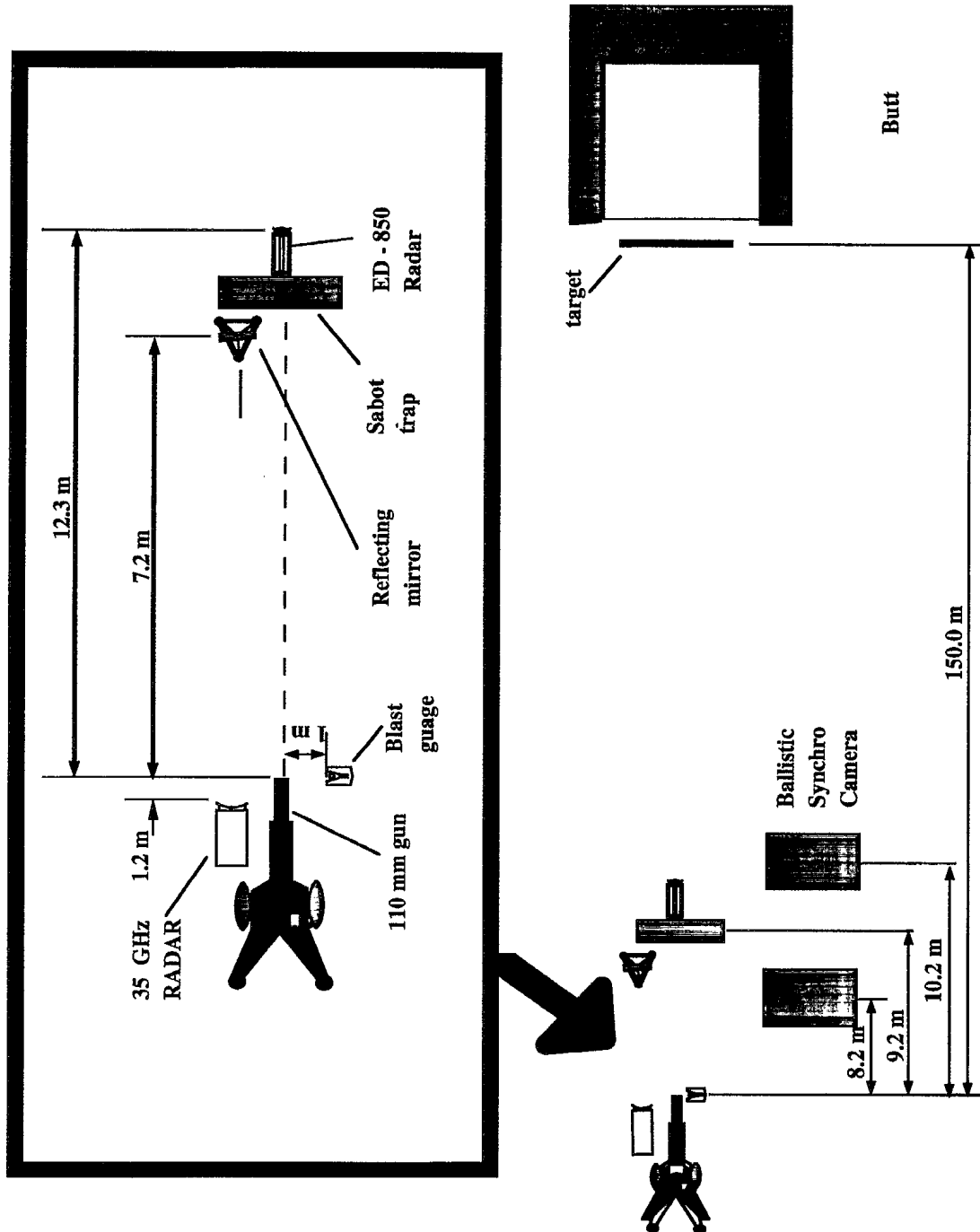
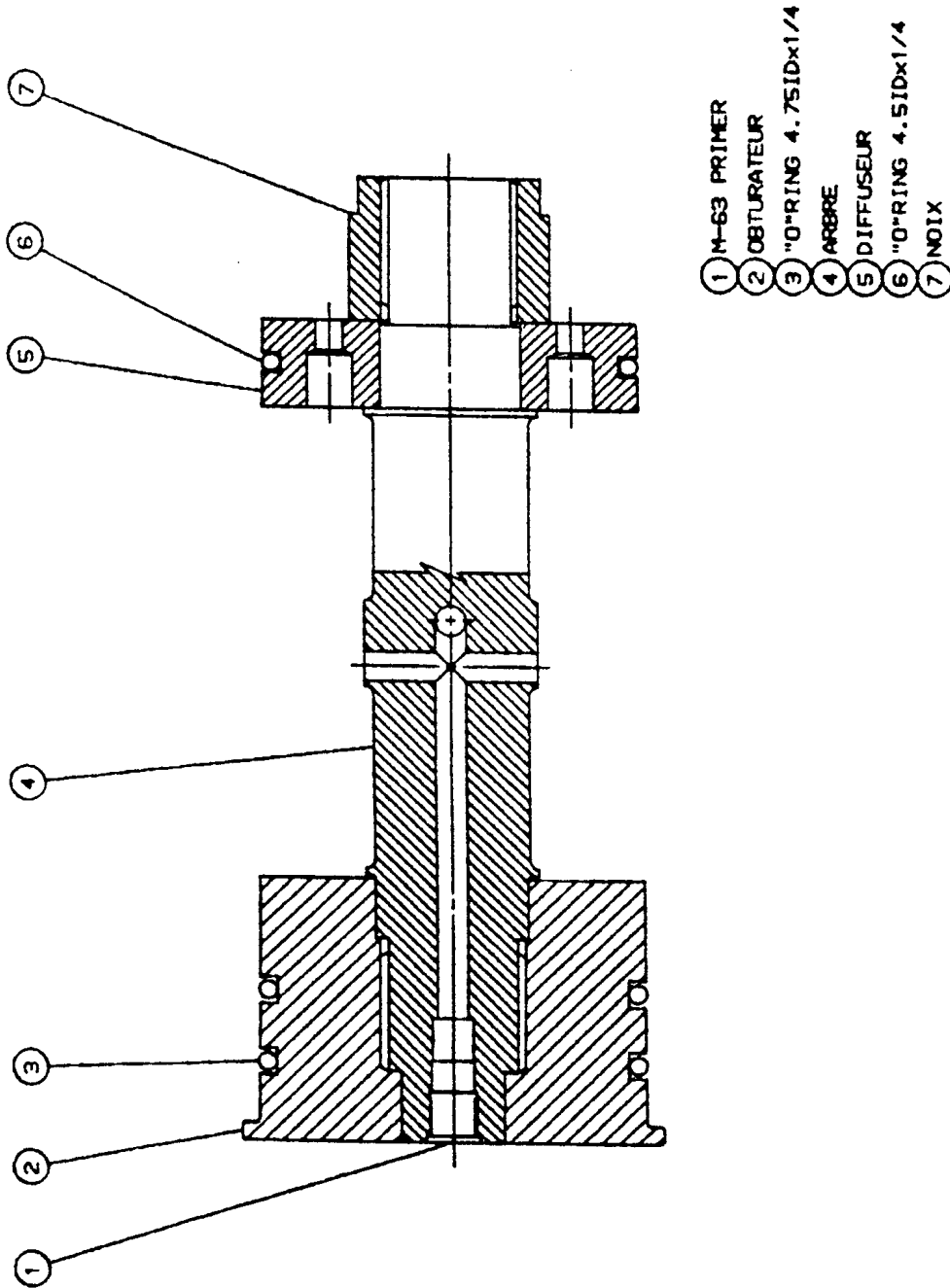


FIGURE 11 - Schematic of the test site

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ADAPTEUR HI/LO
CANON 110 MM SB

FIGURE 12 - Hi-Lo 110 mm chamber adapter

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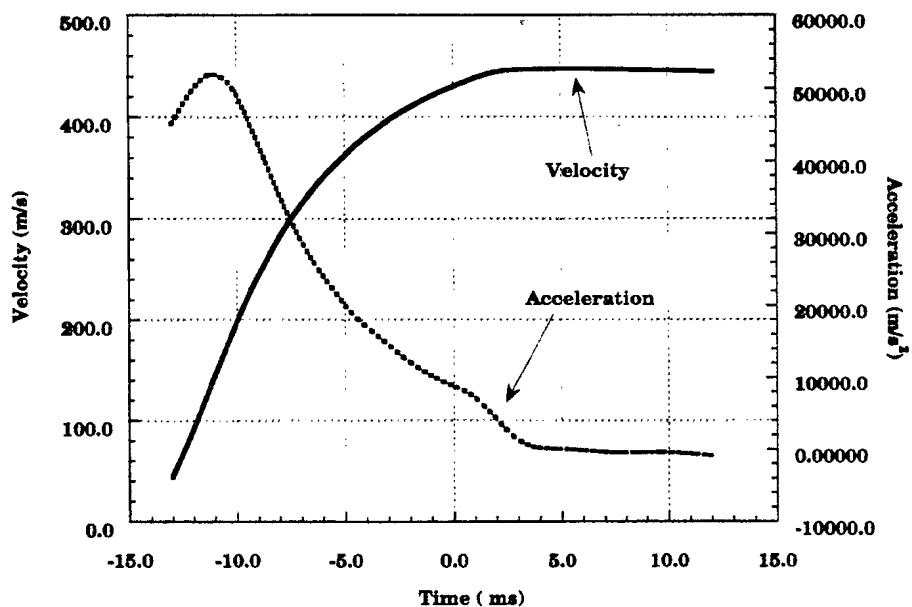


FIGURE 13 - Velocity and acceleration history for Slug A1

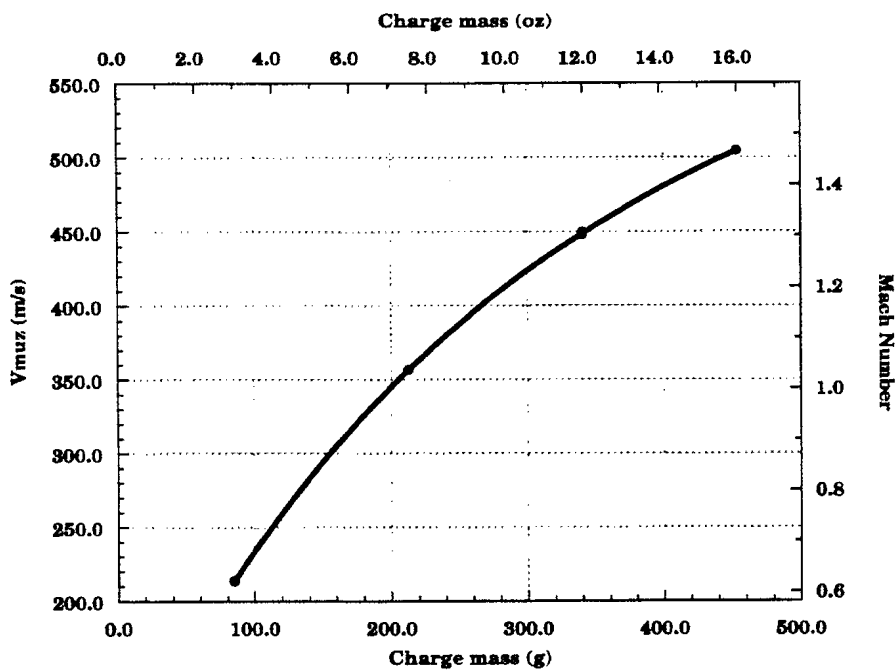


FIGURE 14 - Muzzle velocity verses propellant charge mass for slugs

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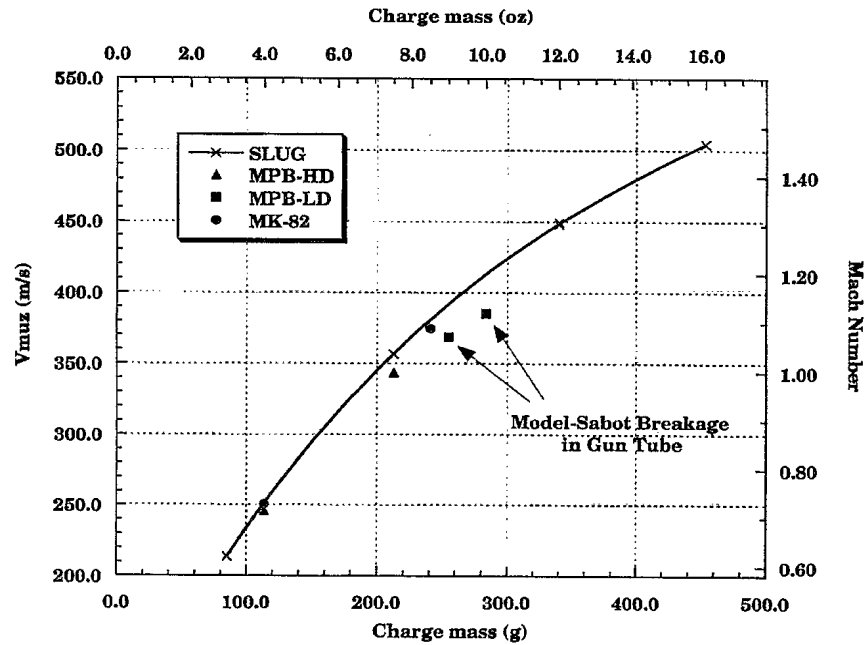


FIGURE 15 - Muzzle velocity versus propellant charge mass for tested projectiles

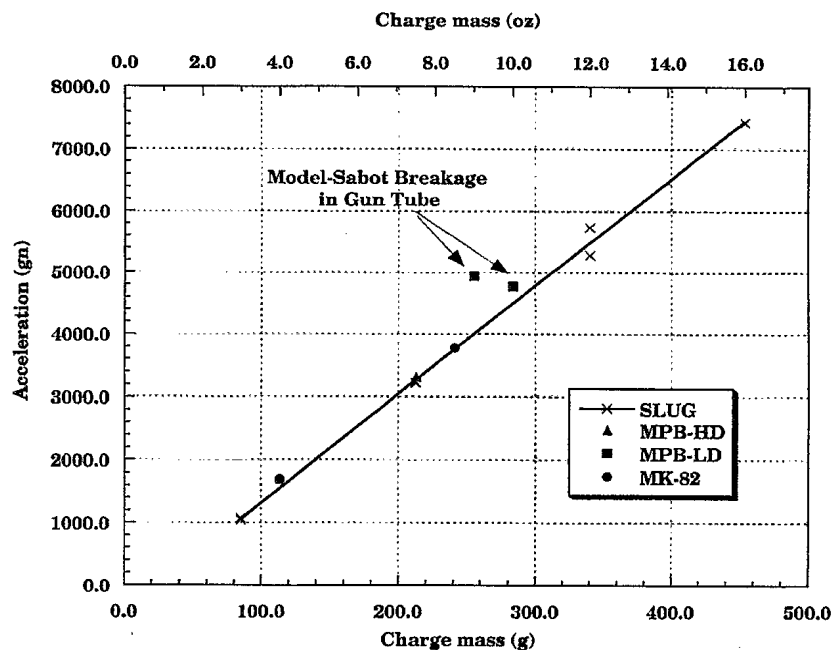
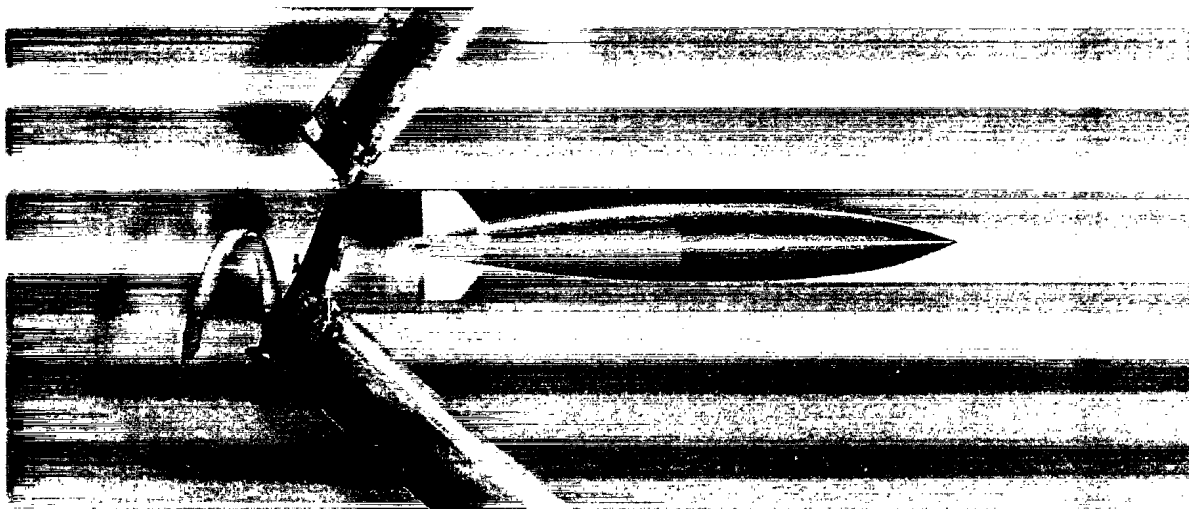


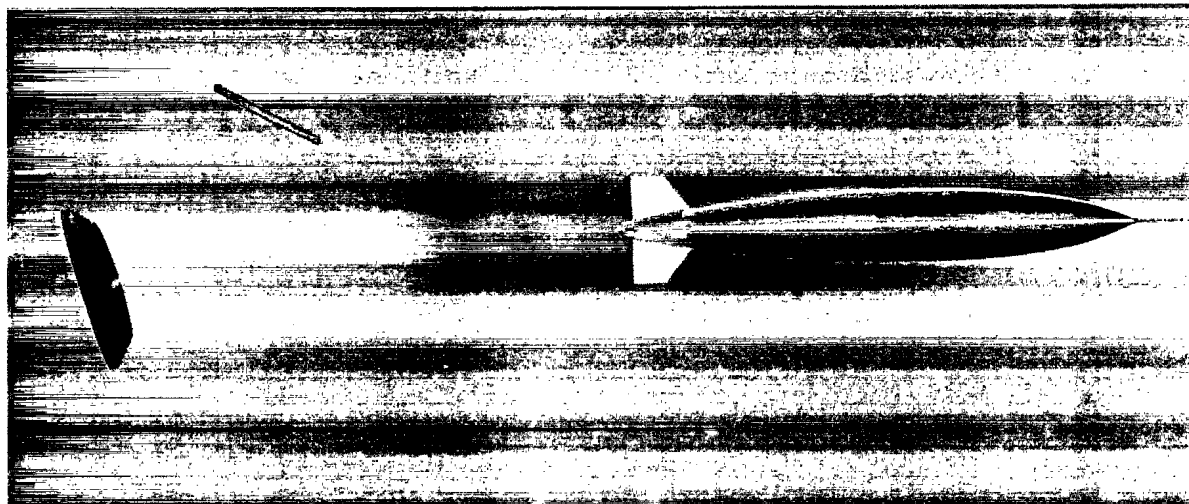
FIGURE 16 - Maximum acceleration achieved versus propellant charge mass for all tests

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FIGURE 17 - Sabot separation for MK-82 - Shot B1, $V_{\text{muz}} = 251 \text{ m/s}$



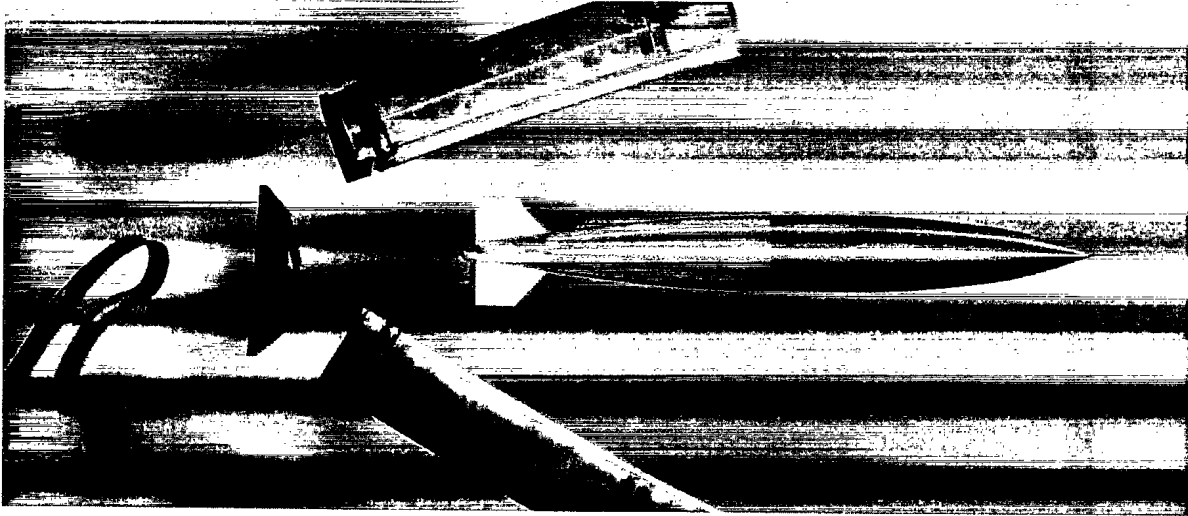
a) Camera 1



b) Camera 2

UNCLASSIFIED

FIGURE 18 - Sabot separation for MK-82 - Shot B2, $V_{\text{muz}} = 375 \text{ m/s}$



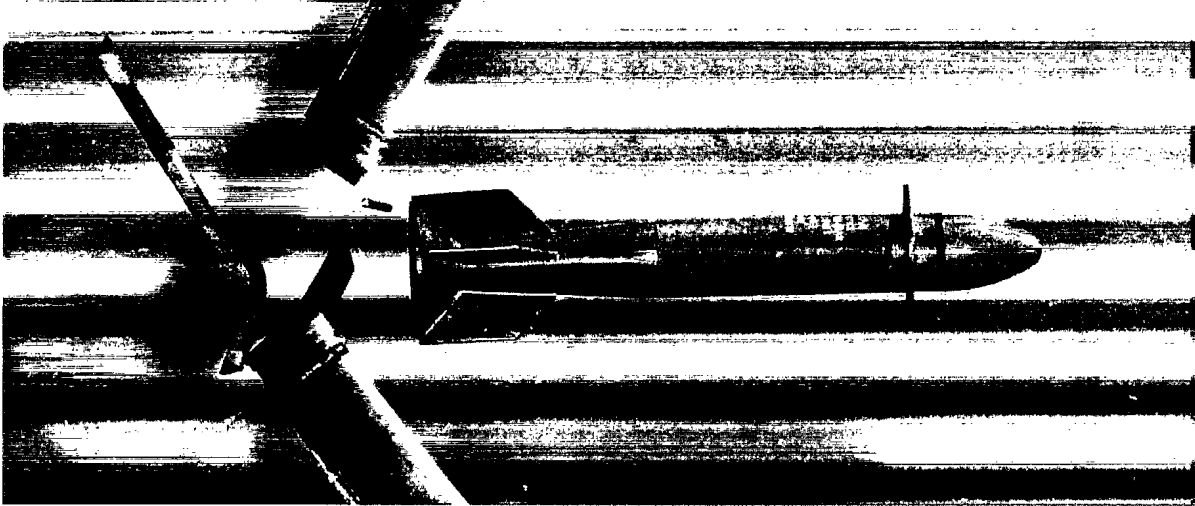
a) Camera 1



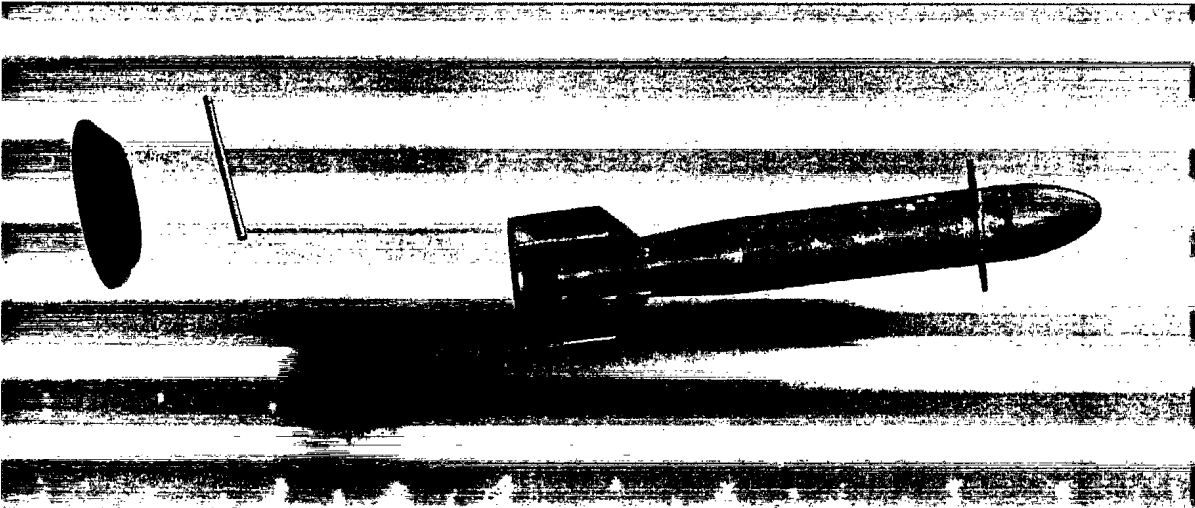
b) Camera 2

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FIGURE 19 - Sabot separation for MPB - HD - Shot D1, $V_{\text{muz}} = 343 \text{ m/s}$



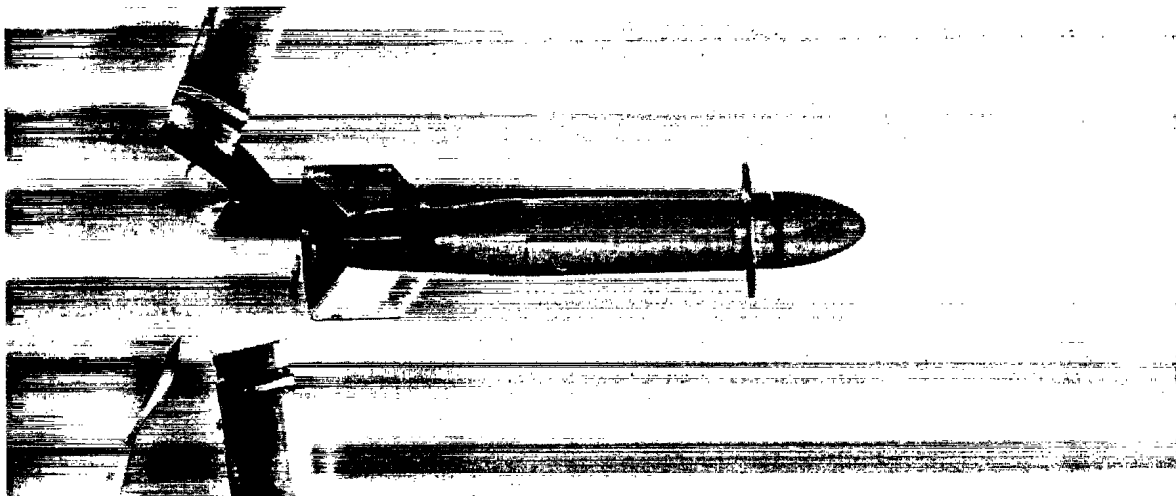
a) Camera 1



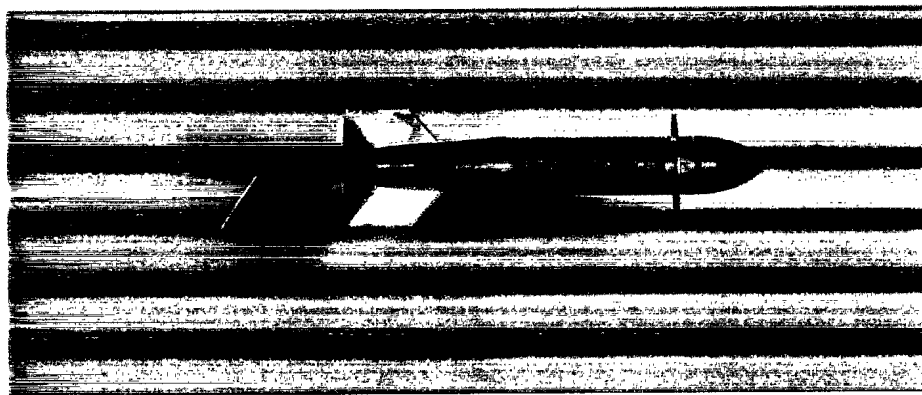
b) Camera 2

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FIGURE 20 - Sabot separation for MPB - HD - Shot D2, $V_{\text{muz}} = 245 \text{ m/s}$



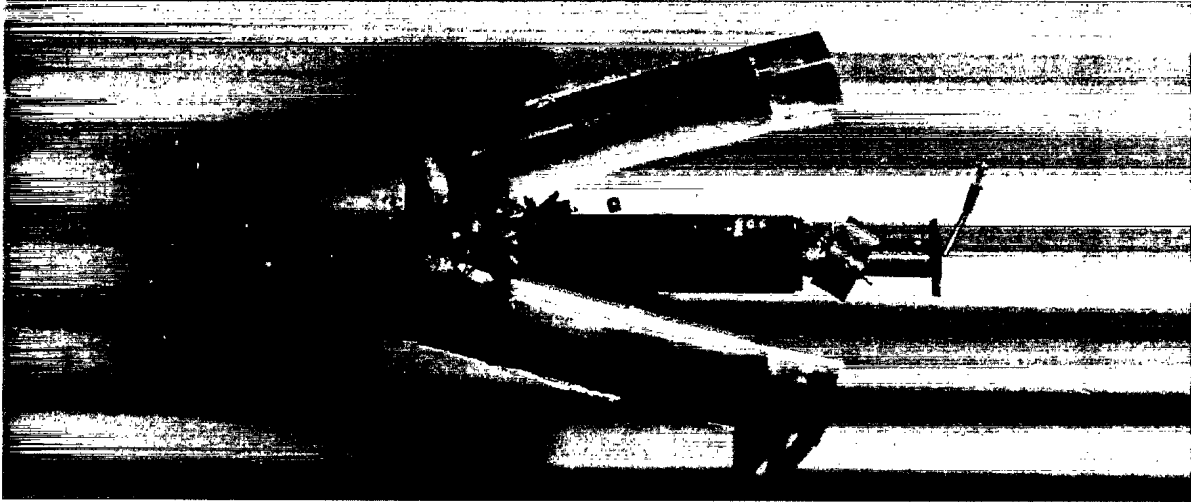
a) Camera 1



b) Camera 2

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FIGURE 21 - Sabot separation for MPB - LD - Camera 1



a) Shot C4, $V_{\text{muz}} = 385 \text{ m/s}$



b) Shot C5, $V_{\text{muz}} = 368 \text{ m/s}$

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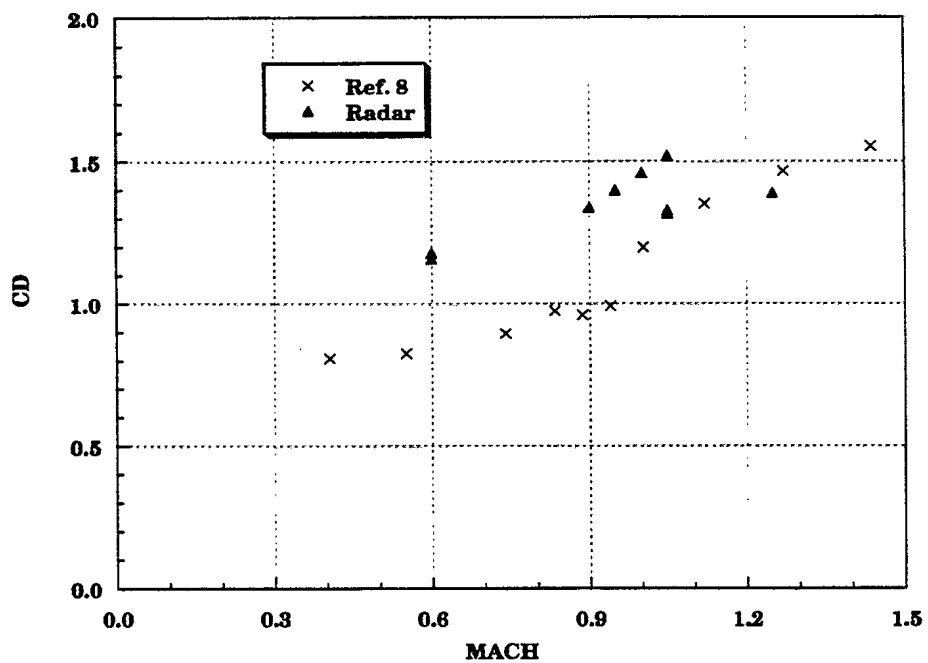


FIGURE 22 - Radar reduced drag coefficient for slugs

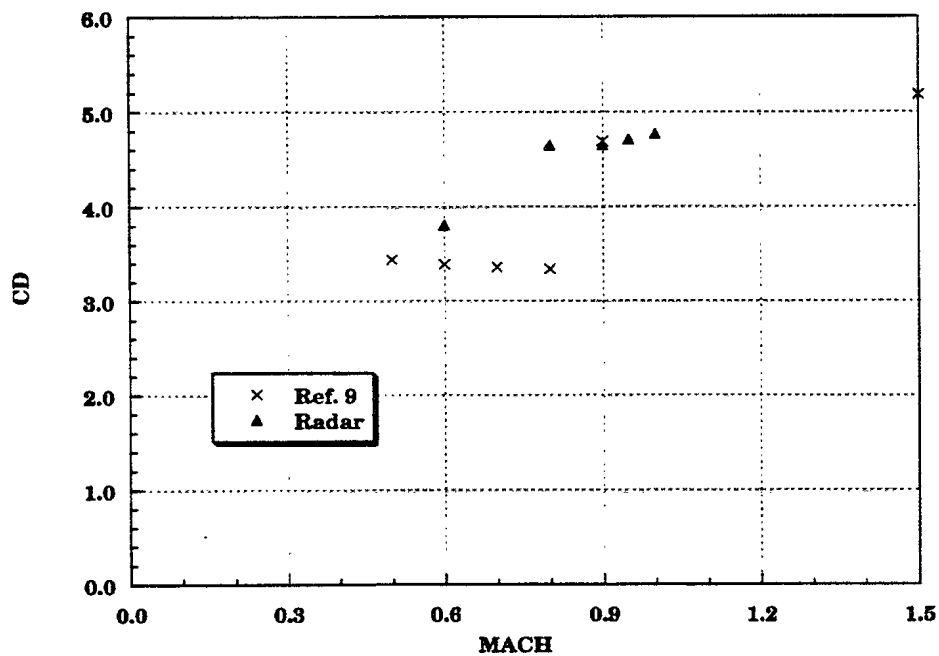


FIGURE 23 - Radar reduced drag coefficient for MPB - HD projectiles

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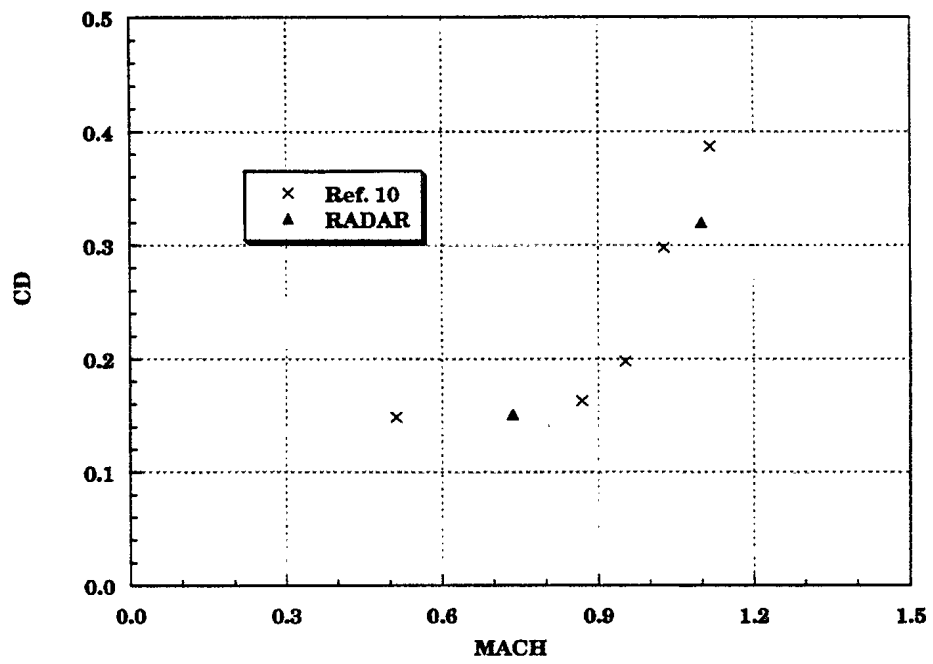


FIGURE 24 - Radar reduced drag coefficient for MK-82 projectiles


APPENDIX A

Detail Drawings of Sabots and Models (dimensions in inches)

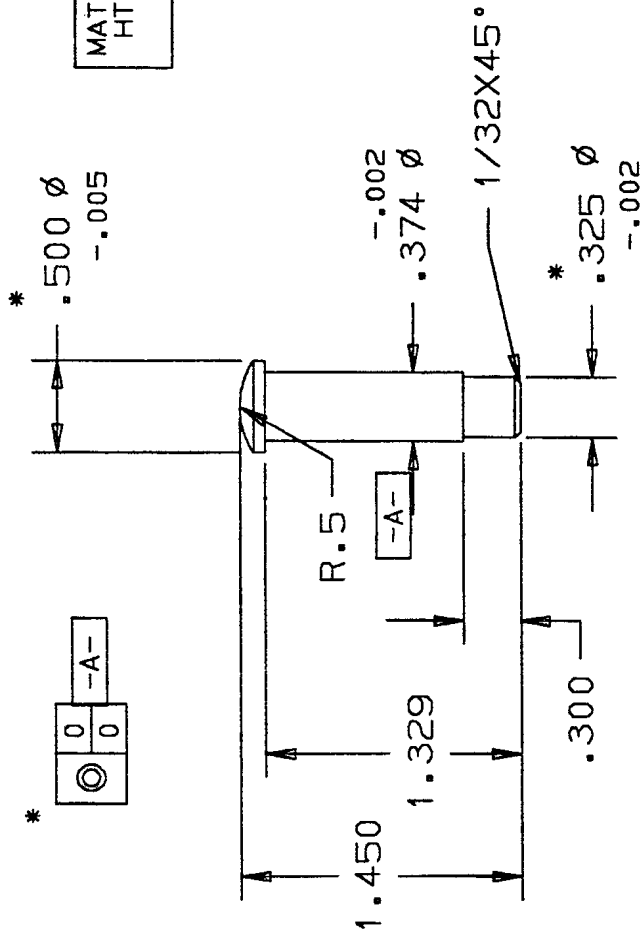
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MPB		MK82		SLUG	
DWG. NO./DESSIN	DESCRIPTION	DWG. NO./DESSIN	DESCRIPTION	DWG. NO./DESSIN	DESCRIPTION
A/96120915	MPB/SABOT/ASSY	A/96111903	MK82/SABOT/ASSY	A/96121119	SLUG/110SB
* 96112006	PIN	* 96112006	PIN	96121120	SLUG
* 96120916	SABOT (MPB)	* 96111801	SABOT (MK82)	96121121	BALLAST
96121017	SABOT (MPB)	96111802	SABOT (MK82)		
96112004	PIN (PIVOT)	* 97260801	PIN (PIVOT)		
96112005	RING	96112005	RING		
96112107	SEAL	96112107	SEAL		
* 96121018	PIN (ROLL) (MPB MODIFIED)	A/96112508	MK82LD		
96121122	DUMMY (SMOKE CART.)	96112509	NOSE		
		96112510	LUG		
		96112511	TAIL		
		96120313	PIN (ROLL) (INDICATOR)		
		96112510	LUG/ASSY PROCEDURE		

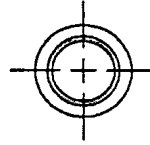
* DRAWINGS AMENDED

SAUF INDICATIONS CONTRAIRES UNLESS OTHERWISE SPECIFIED		SYMB.	MOD./AMEND.	DATE
DIMENSIONS: IN. - FINI DE SURFACE SURFACE FINISH 			MAETEC	
TOLERANCES: DECIMALES, DECIMALS (X) (X) ± .02 (XX) ± .01 (XXX) ± .005 ANGLES ± 0°-30'		CONCEP. m. normand 12/12/96	NON NAME MPB/MK82/SLUG (DRAWING LIST)	
		DATE	DESSIN NO. DWG. 96121123	

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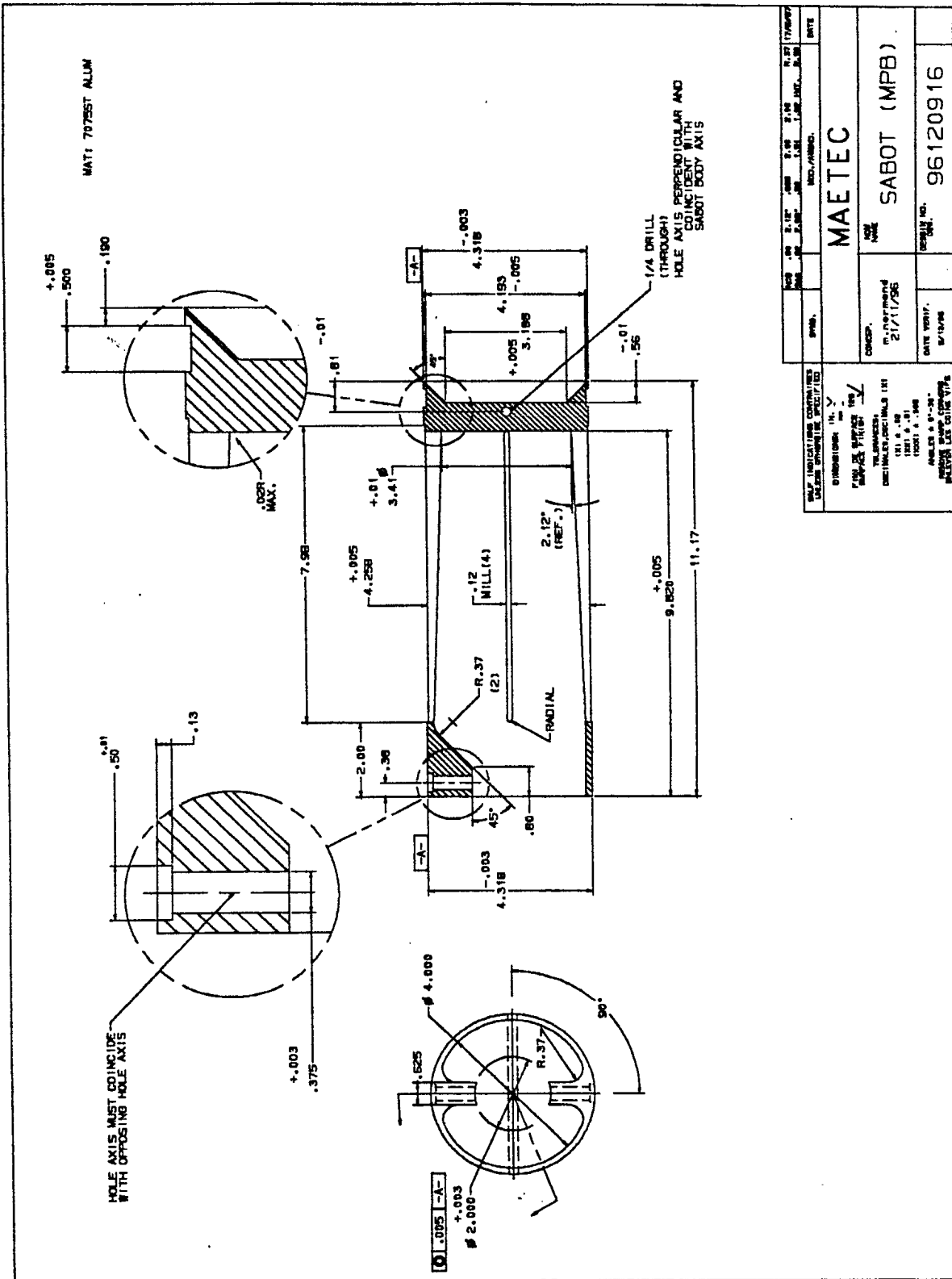


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HT. TREAT AND HDN.
ROC. "C" 52-55



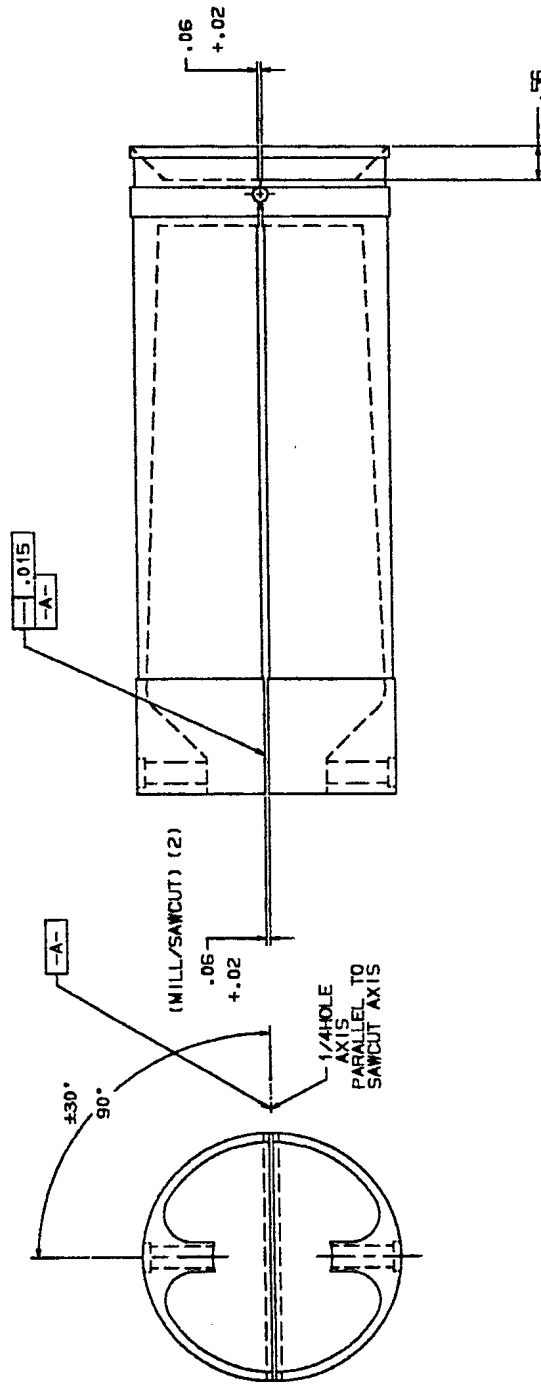
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CONCEPT m.bernard 20/11/96	NEW NAME PIN	DATE OF BIRTH 96112006
DATE OF BIRTH 1991.06.11 1991.06.11 1991.06.11	DATE OF BIRTH 1991.06.11 1991.06.11 1991.06.11	DATE OF BIRTH 1991.06.11 1991.06.11 1991.06.11

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MAT: ITEM DWG. NO. 96120916



DATE	SYMB.	MOD./AMEND.	DATE
MAETEC			
CONCEPT	DATE	NAME	
18/11/96		SABOT (MPB)	
DATE VERIF.	DESIGN NO.	OBJ.	
8/12/96	96121017		

UNIT INDICATING CONTAINERS
UNLESS OTHERWISE SPECIFIED

DIMENSIONS: IN. $\frac{1}{16}$

FINI DE SURFACE $\frac{1}{16}$

SURFACE FINISH

TOLERANCES:

DECIMALS DECIMALS (X)

(X) $\pm .02$

(X) $\pm .01$

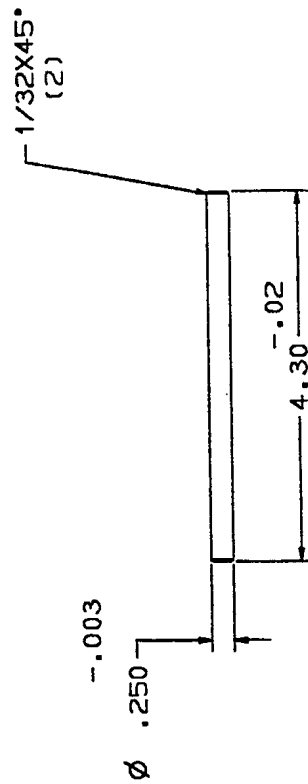
(X) $\pm .005$

ANGLES $\pm 9^\circ-30'$

REMOVE SLOTTED RECESSES

ENLEVER LES COULETTES

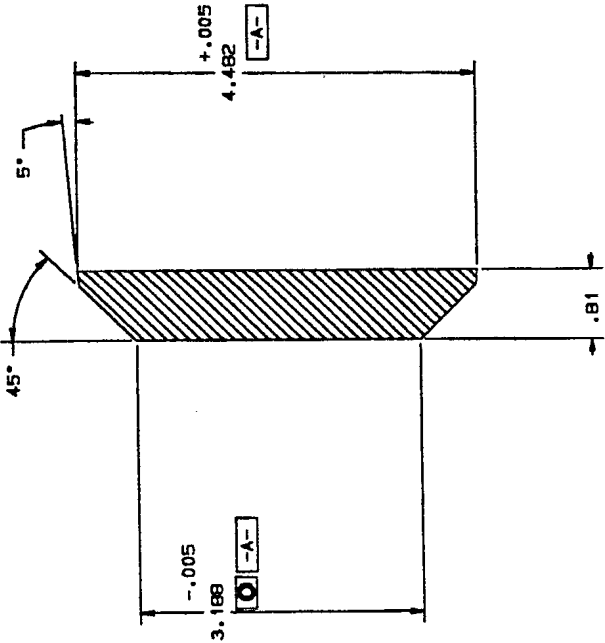
MAT: 1/4_ALUM ROD




1. NAME (LAST, FIRST, MIDDLE) 2. DATE OF BIRTH (MM/DD/YYYY) 3. SEX (M/F) 4. ADDRESS (STREET, CITY, STATE, ZIP) 5. PHONE (AREA CODE, NUMBER) 6. OCCUPATION 7. EDUCATION 8. MARITAL STATUS 9. NUMBER OF CHILDREN 10. DATE OF ENTRY (MM/DD/YYYY)	11. GRADE 12. SCHOOL 13. DISTRICT 14. COUNTY 15. STATE	16. SIGNATURE 17. DATE (MM/DD/YYYY)	18. NAME (LAST, FIRST, MIDDLE) 19. DATE OF BIRTH (MM/DD/YYYY) 20. SEX (M/F) 21. ADDRESS (STREET, CITY, STATE, ZIP) 22. PHONE (AREA CODE, NUMBER) 23. OCCUPATION 24. EDUCATION 25. MARITAL STATUS 26. NUMBER OF CHILDREN 27. DATE OF ENTRY (MM/DD/YYYY)
1. NAME (LAST, FIRST, MIDDLE) 2. DATE OF BIRTH (MM/DD/YYYY) 3. SEX (M/F) 4. ADDRESS (STREET, CITY, STATE, ZIP) 5. PHONE (AREA CODE, NUMBER) 6. OCCUPATION 7. EDUCATION 8. MARITAL STATUS 9. NUMBER OF CHILDREN 10. DATE OF ENTRY (MM/DD/YYYY)	11. GRADE 12. SCHOOL 13. DISTRICT 14. COUNTY 15. STATE	16. SIGNATURE 17. DATE (MM/DD/YYYY)	18. NAME (LAST, FIRST, MIDDLE) 19. DATE OF BIRTH (MM/DD/YYYY) 20. SEX (M/F) 21. ADDRESS (STREET, CITY, STATE, ZIP) 22. PHONE (AREA CODE, NUMBER) 23. OCCUPATION 24. EDUCATION 25. MARITAL STATUS 26. NUMBER OF CHILDREN 27. DATE OF ENTRY (MM/DD/YYYY)

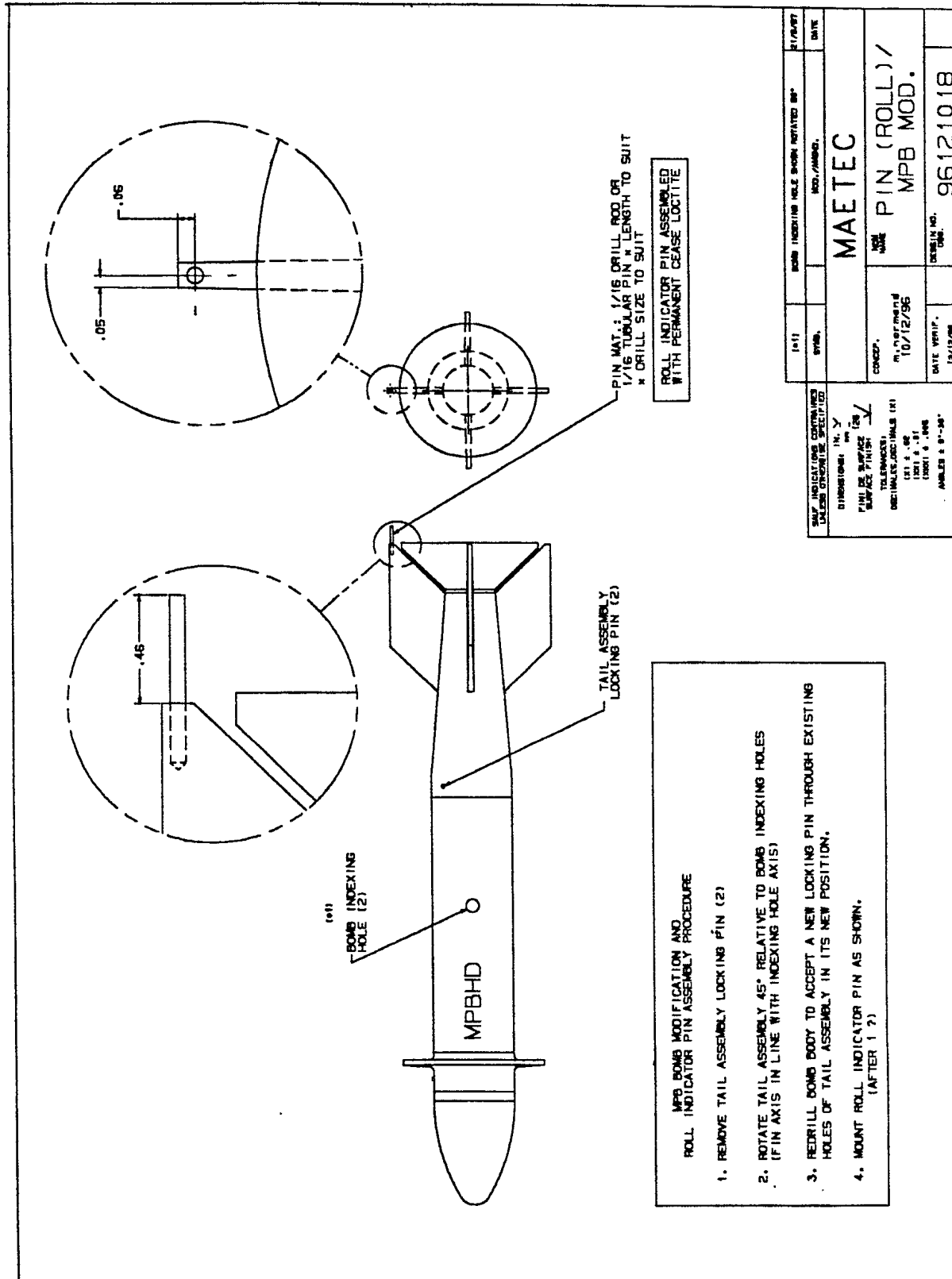
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MAT: NEOPRENE RUBBER
SHORE HD'NS 55



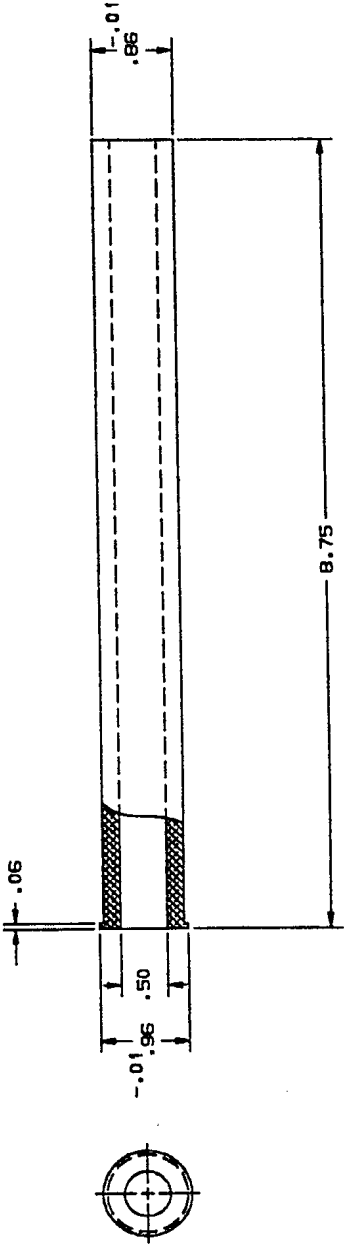
SAUF INDICATIONS CONTRAIRES UNLESS OTHERWISE SPECIFIED		SYMB.	MOD./AMEND.	DATE
DIMENSIONS: IN. $\frac{1}{16}$ = 		MAETEC		
FINI DE SURFACE SURFACE FINISH		CONCEPT	SEAL	
TOLERANCES		NOM NAME		
DECIMALES/DECIMALS (X)		M. APPROVED 27/11/96		
(X) \pm .02		DATE VERIF. 5/12/96		
(X) \pm .01				
(X) \pm .005		DESSIN NO. DWB.		
ANGLES \pm 9°-30° RENDER SHARP EDGES ENLEVER LES COINS VIFS		96112107		

UNCLASSIFIED



SAMP. INDICATING CONTAINED BOMB ORIGINALLY ASSEMBLED		BOMB INDEXING HOLE SHOWN ROTATED 90°		21/8/97
DIRECTIONS: N.Y.		BY:	NO. / AMNO.	DATE
FIN DE SURFACE (2) <input checked="" type="checkbox"/>		MAETEC		
SURFACE FINISH		NEW PIN (ROLL) / MPB MOD.		
TOLERANCES:		CONCEPT		
DIM. VALUES (JOC. HOLE) (2)		M. 10/12/96		
(2) ± .02		DATE WRUP.		
(2) ± .01		12/12/96		
(2) ± .005		DOWEL NO.		
ANGLES ± 0°-30°		96121018		

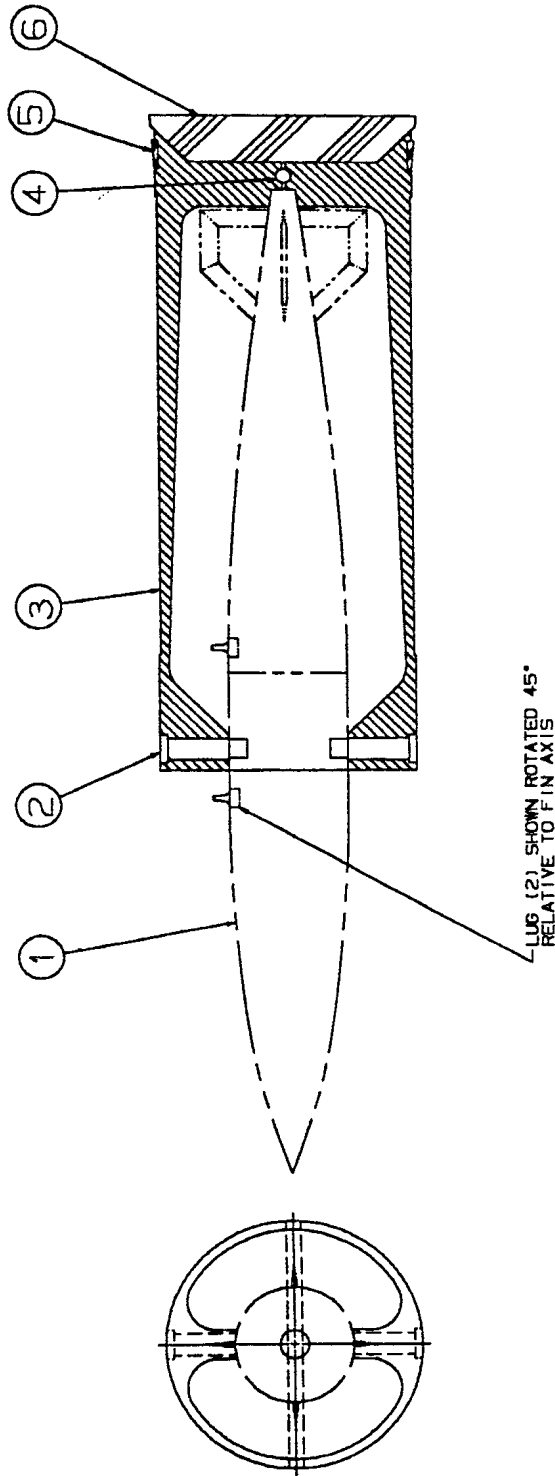
MAT: ALUM



PART IDENTIFICATION SPECIFICATIONS		REV.	REV. / AMEND.	DATE
PART NAME: MAETEC				
PART NUMBER: 96121122				
TOLERANCES: UNLESS OTHERWISE SPECIFIED				
DIMENSIONS: DECIMALS (12)				
FRACTIONS: 1/16, 1/8, 1/4, 3/8, 1/2, 5/8, 3/4, 7/8				
ANGLES: 15°, 30°, 45°, 60°, 90°, 120°, 135°, 150°, 165°, 180°				
DATE: 12/12/95				
DRAWN BY: 96121122				

UNCLASSIFIED

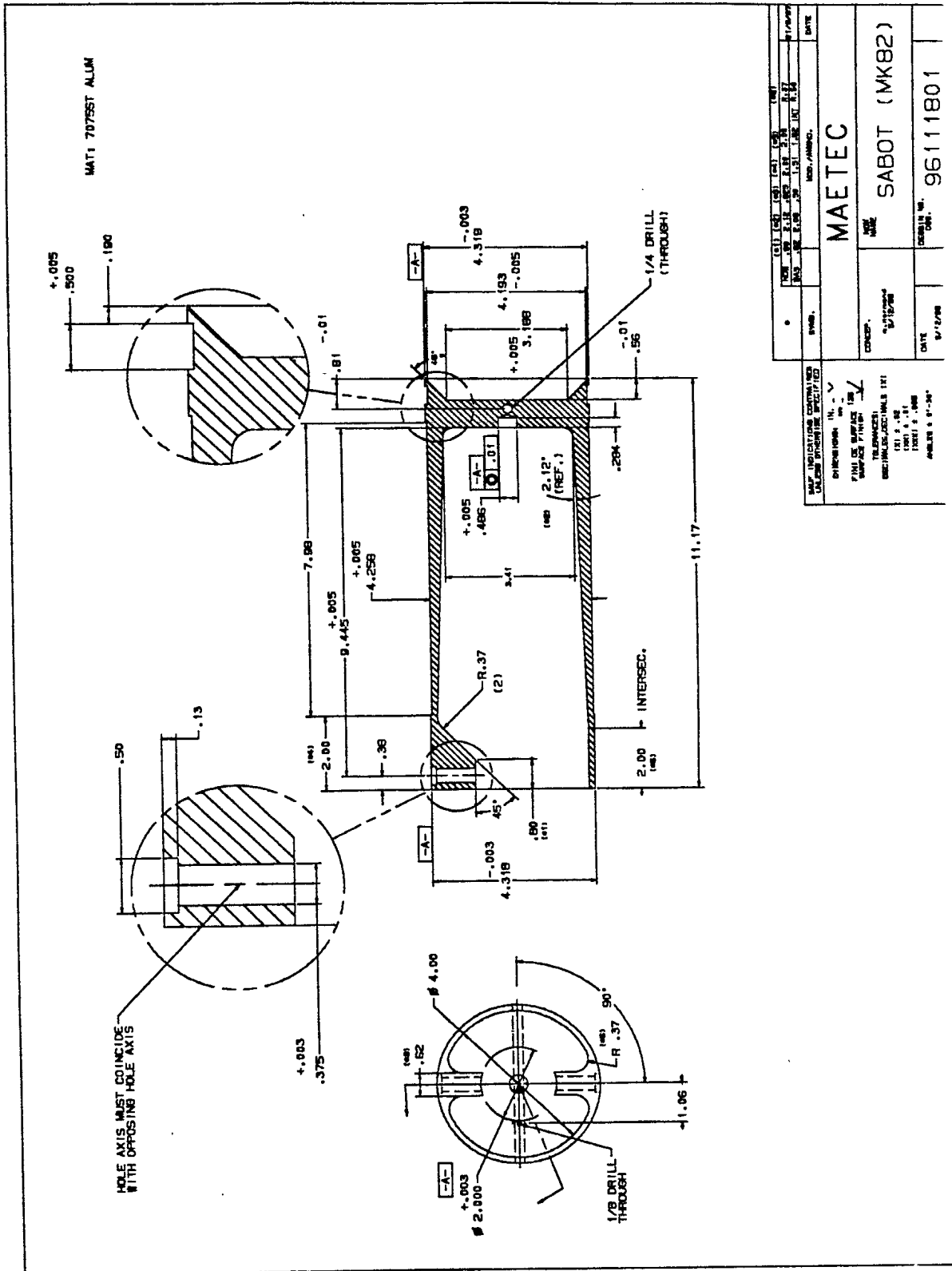
ITEM	DWG. NO./DESSIN	DESCRIPTION	REQ.
1	A/96112508	MK82LD PROJECTILE (4 DRAWINGS)	1
2	96112006	PIN	2
3	96111801/02	SABOT (2 DRAWINGS)	1
4	96112004	PIVOT PIN	1
5	96112005	RING	1
6	96112107	SEAL	1



LUG (2) SHOWN ROTATED 45°
RELATIVE TO FIN AXIS

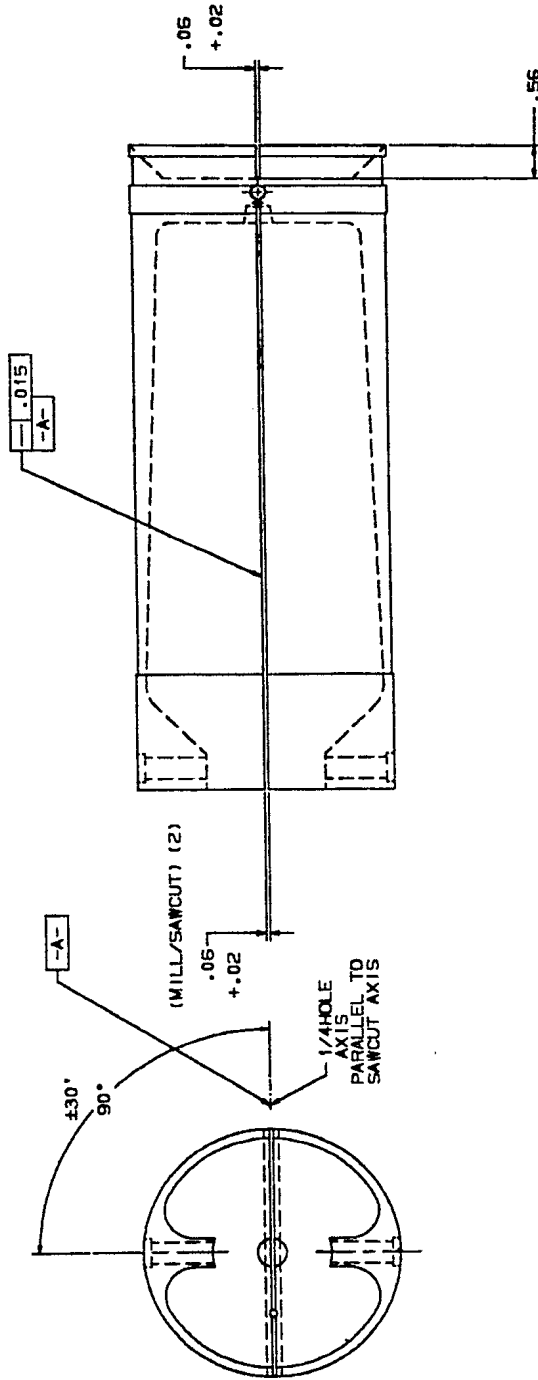
DWG. NO./DESSIN		SYMB.		MOD./AMEND.		DATE	
A/96112508				MAETEC			
CONCEPT		CONCEPT		NON NAME		MK82/SABOT/ASSY	
DATE VERIF.		DATE VERIF.		DESIGN NO.		A/96111903	
5/12/96		5/12/96		0001			

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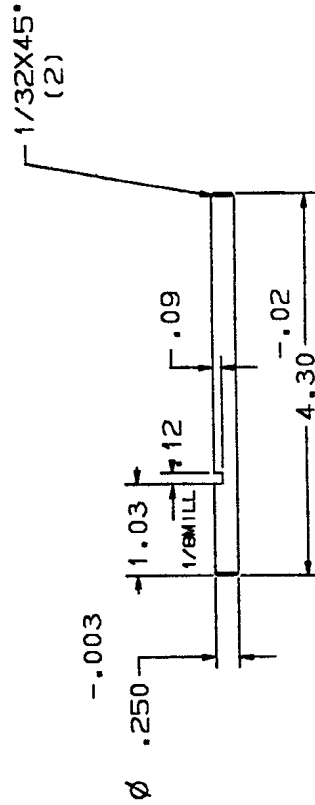
MAT: ITEM DNG. NO. 96111801



SAUF INDICATIONS CONTRAIRES UNLESS OTHERWISE SPECIFIED		SYMB.	MOD./MÉMO.	DATE
DIMENSIONS IN. Y		MAETEC		
FINI DE SURFACE 125/		NON		
SURFACE FINISH		NAME SABOT (MK82)		
TOLERANCES		CONCEPT		
DECIMALES/DECIMALS (X)		7/8/11/86		
(X) ± .02		DATE VERIF.		
(XX) ± .01		5/12/86		
(XXX) ± .005		DESIGN NO.		
ANGLES ± 0°-30°		96111802		
REMOVE SURFACES ENLEVER LES COUS VITE				

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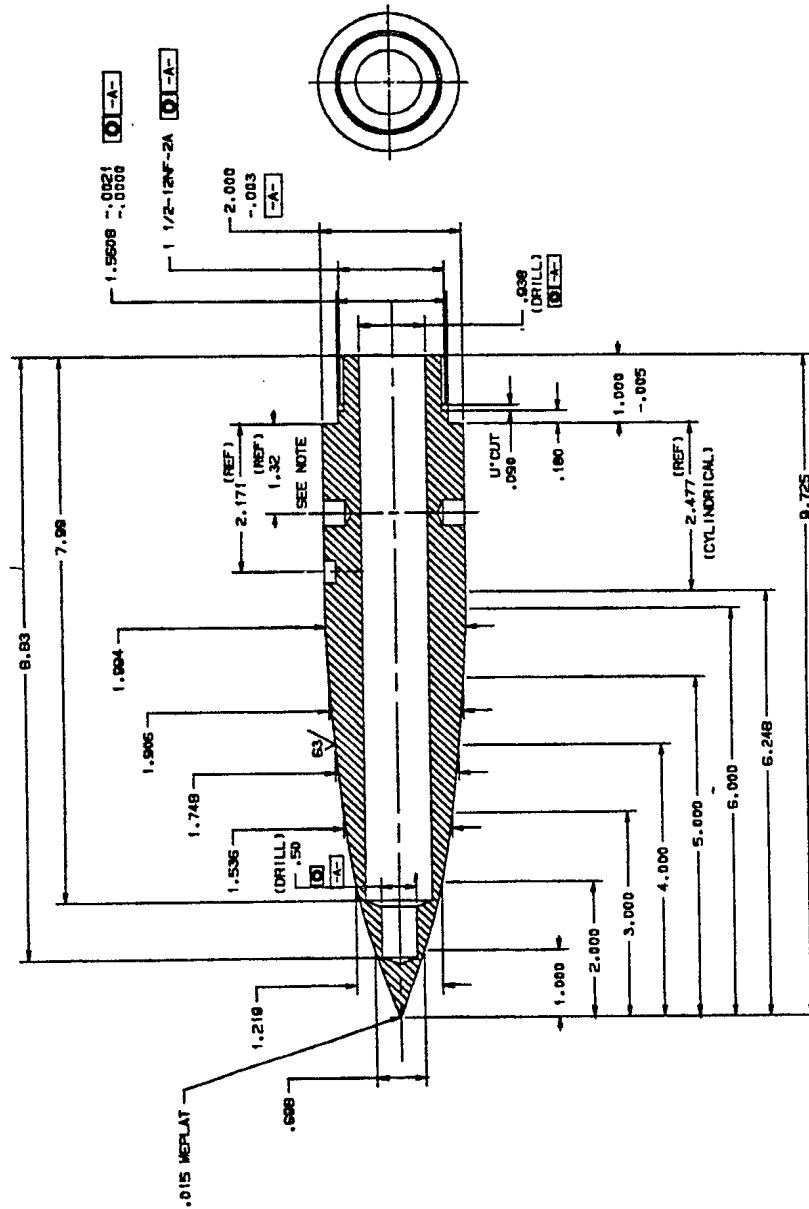
MAT: 1/4 ALUM ROD



DATE	REV.	REV. / AMEND.	DATE
		MAETEC	
DATE	REV.	REV.	DATE
20/11/96	1	PIN, PIVOT	
DATE	REV.	REV.	DATE
01/09/96	1	97260801	

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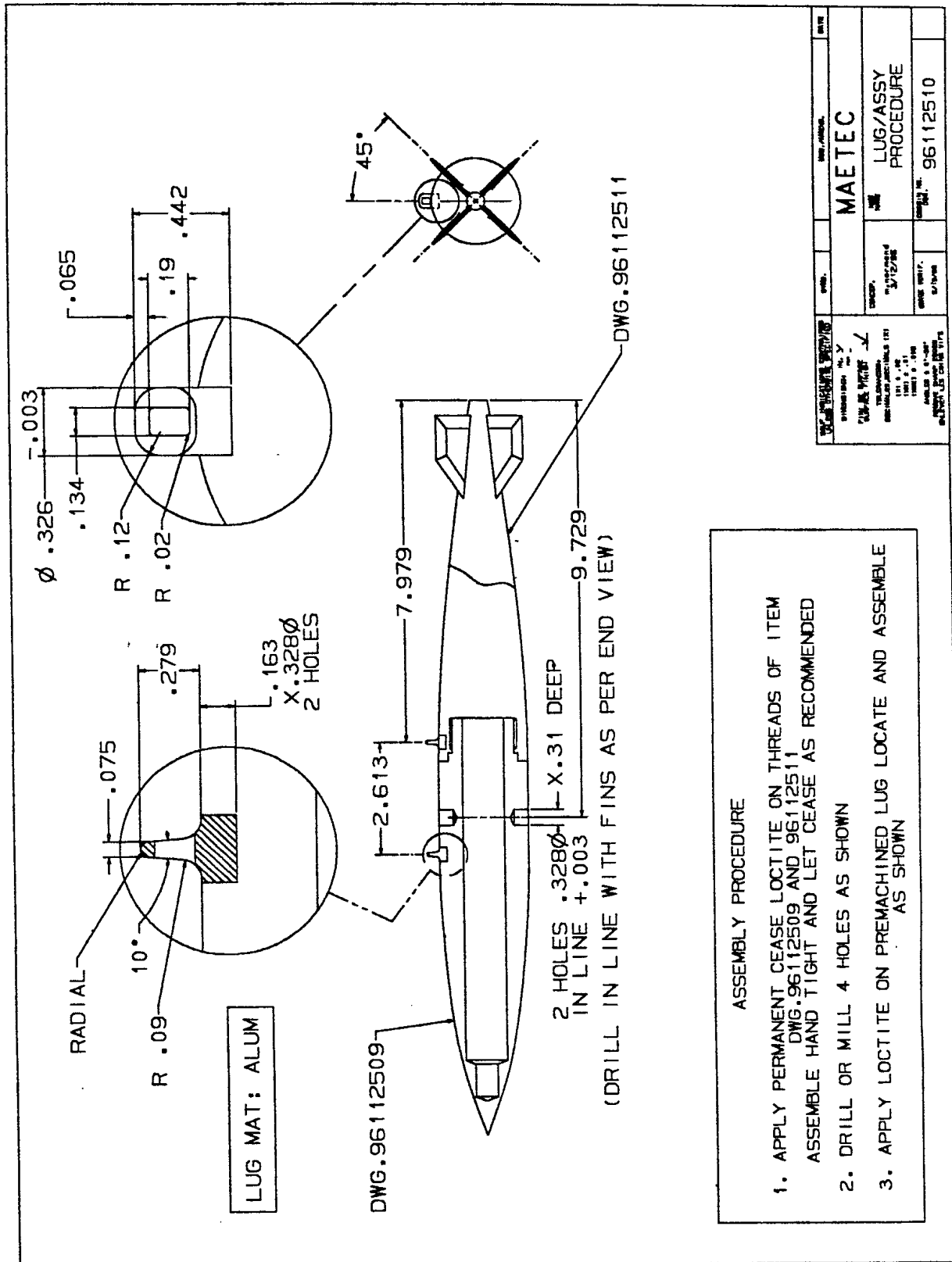
MAT: MILD STEEL (CRS)



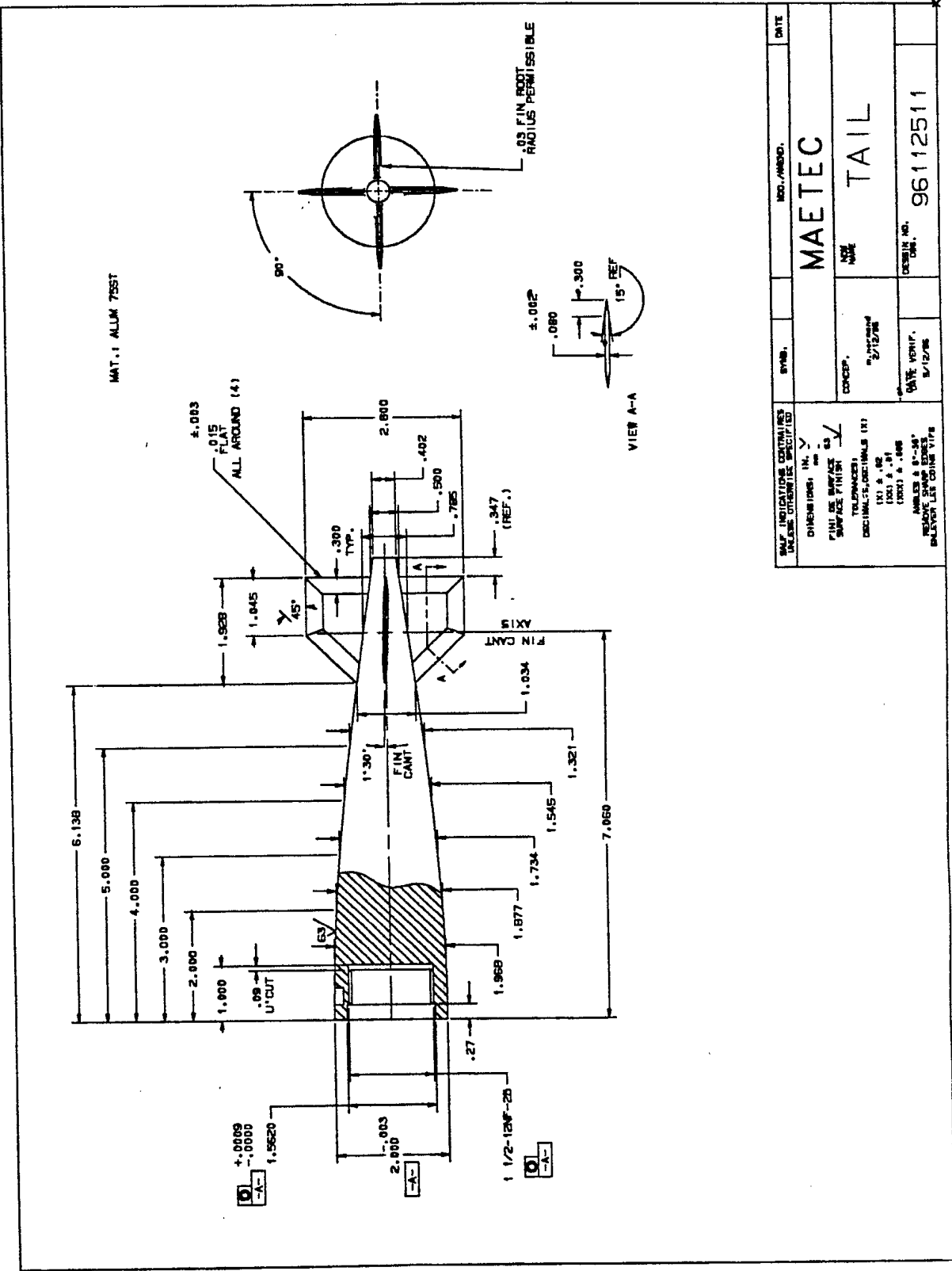
NOTE: 3 HOLES DRILLED IN CONJUNCTION
WITH DRAWING NO. 96112510
AT ASSEMBLY

SELF INDICATING CONTAINERS UNLESS OTHERWISE SPECIFIED	DIRECTIONS: N. <input checked="" type="checkbox"/> S. <input type="checkbox"/> E. <input type="checkbox"/> W. <input type="checkbox"/>	SYMB.	MOD./MEND.	DATE
FILM DE SURFACE SURFACE FINISH TOLERANCES DECIMALS DECIMALS (N) (X1) & .02 (X1) & .01 (X1) & .005 ANGLES & 90° REMOTE SHARP CORNERS	CONCEPT NO NAME NOSE	DESIGN NO. DWA. 96112509		

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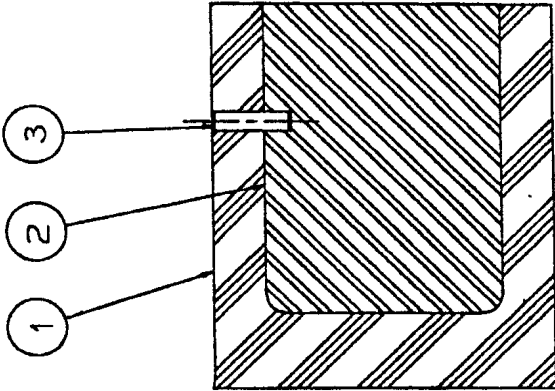
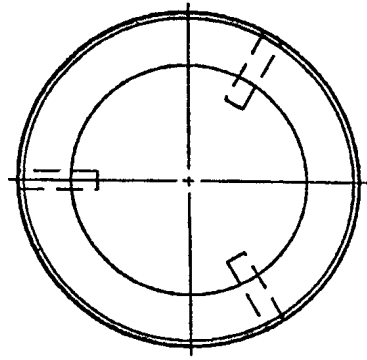


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ITEM	DWG. NO./DESSIN	DESCRIPTION	REQ.
1	96121120	SLUG	1
2	96121121	BALLAST	1
3	ND	PIN (TUBULAR 1/40 DIA. x 1 PD. LG.)	3

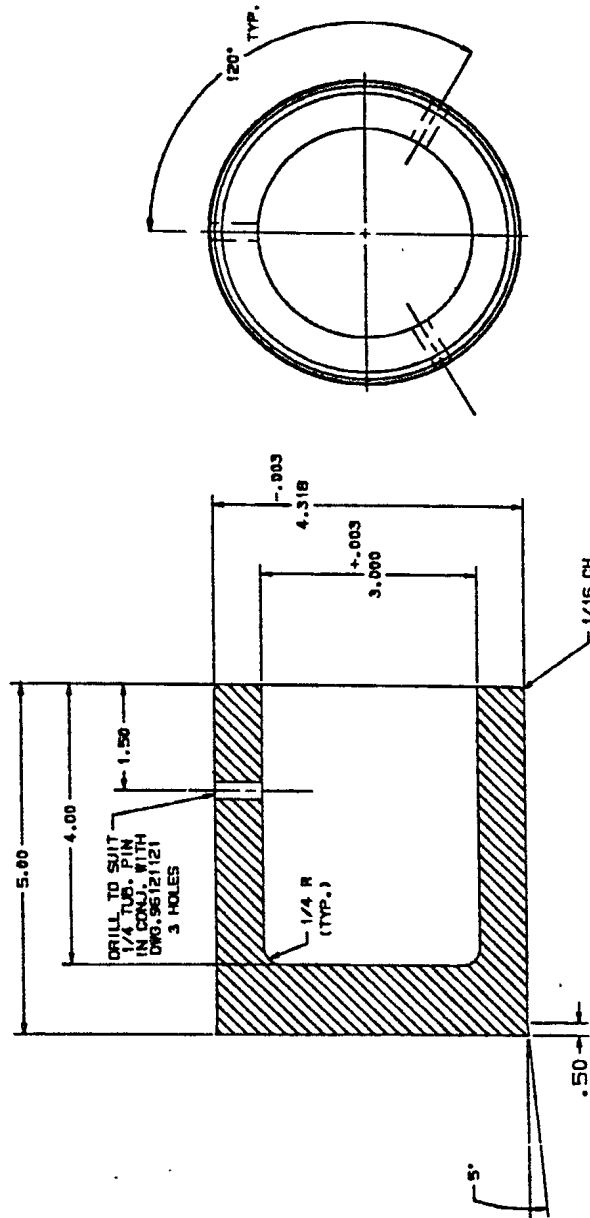



SYMB.		MOD./AMOD.	DATE
MAETEC			
CONCEP.	REV. NAME	SLUG/110SB	
P. APPROVED 11/12/96			
DATE VERIF.	DESIGN NO.	A/96121119	
12/12/96	DRG.		

<p>SAUF INDICATIONS CONTRAIRES TOLERANCES SPECIFIEES</p> <p>DIMENSIONS: IN. $\sqrt{}$ mm $\sqrt{}$</p> <p>FINI DE SURFACE $\sqrt{}$</p> <p>SURFACE FINISH</p> <p>TOLERANCES:</p> <p>DECIMALES DECIMALES (X)</p> <p>(X) $\pm .02$</p> <p>(XX) $\pm .01$</p> <p>(XXX) $\pm .005$</p> <p>ANGLES $\pm 0^\circ-30^\circ$</p>

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MAT: POLYCARBONATE

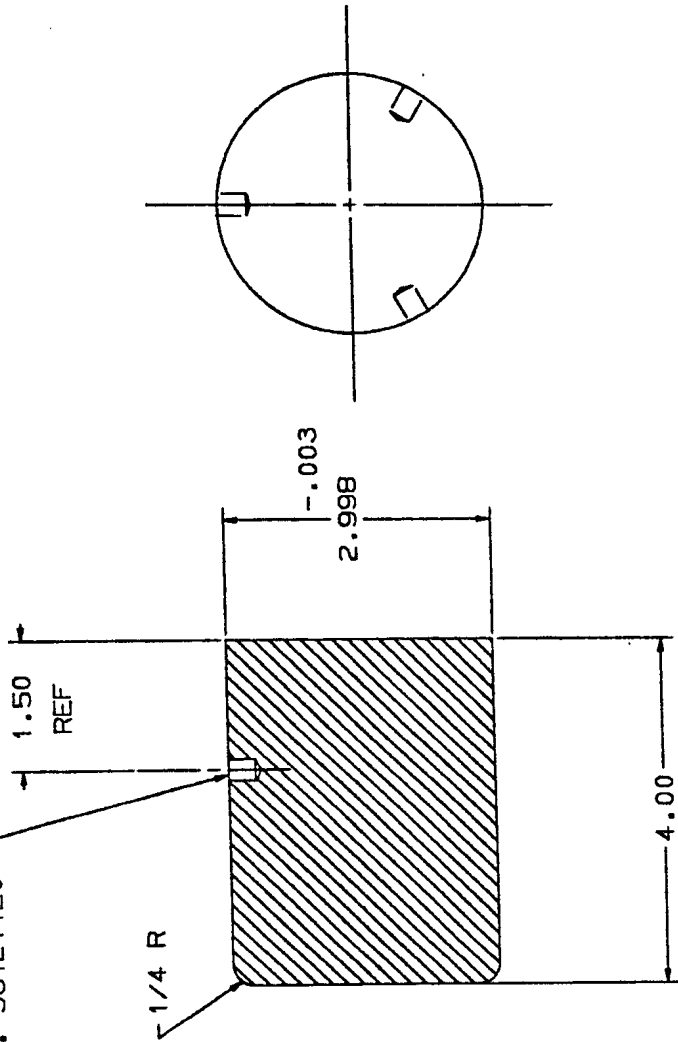


DATE	REV.	NO.	DATE
12/12/96	1	MAETEC	
CONCEPT	M. NORMAND	NAME	SLUG
DATE VERIF.	12/12/96	DESIGN NO.	96121120

DIMENSIONS IN INCHES
 FINI DE SURFACE
 SURFACE FINISH
 TOLERANCES
 DECIMALES DECIMALES (D)
 (D) & .00
 (D) & .01
 (D) & .005
 ANGLES & 9'-30"
 REMOVE SURF. CORNER
 SAUF LES DONS VUE

MAT:MILD STEEL

3 HOLES DRILL
IN CONJ. WITH
DWG. 96121120

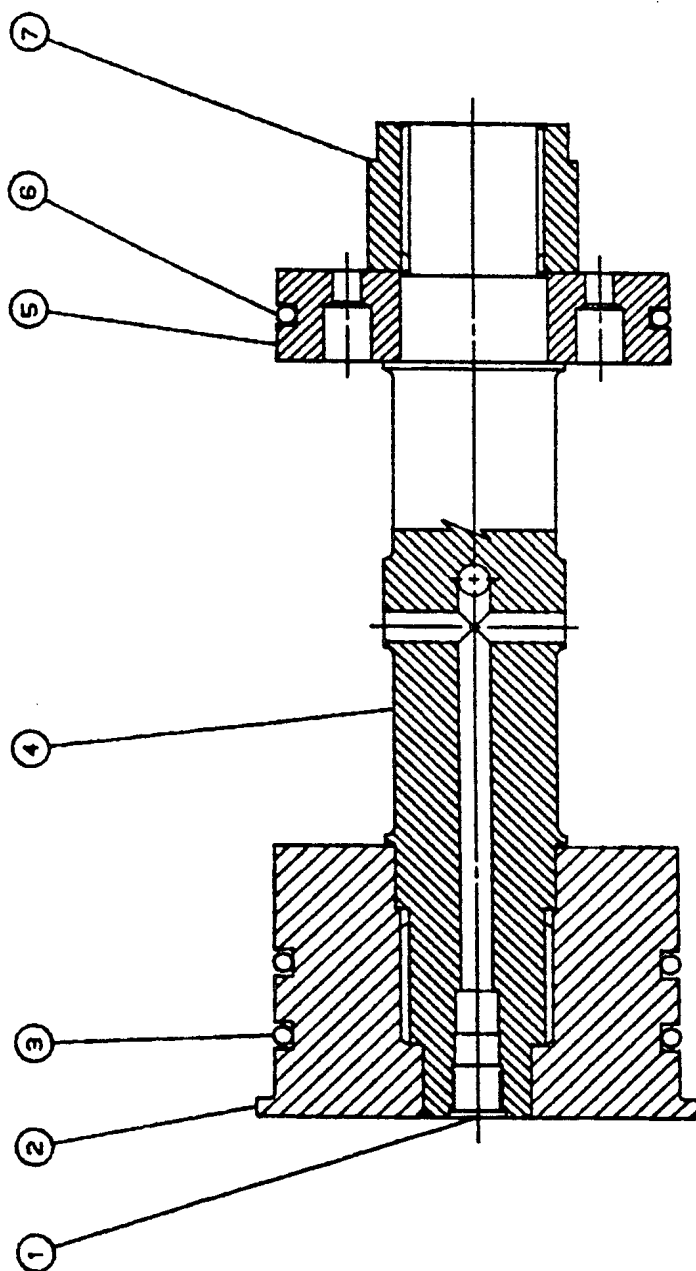


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APPENDIX B

Detail Drawings of 110 mm Gun Hi - Lo Adapter (dimensions in inches)

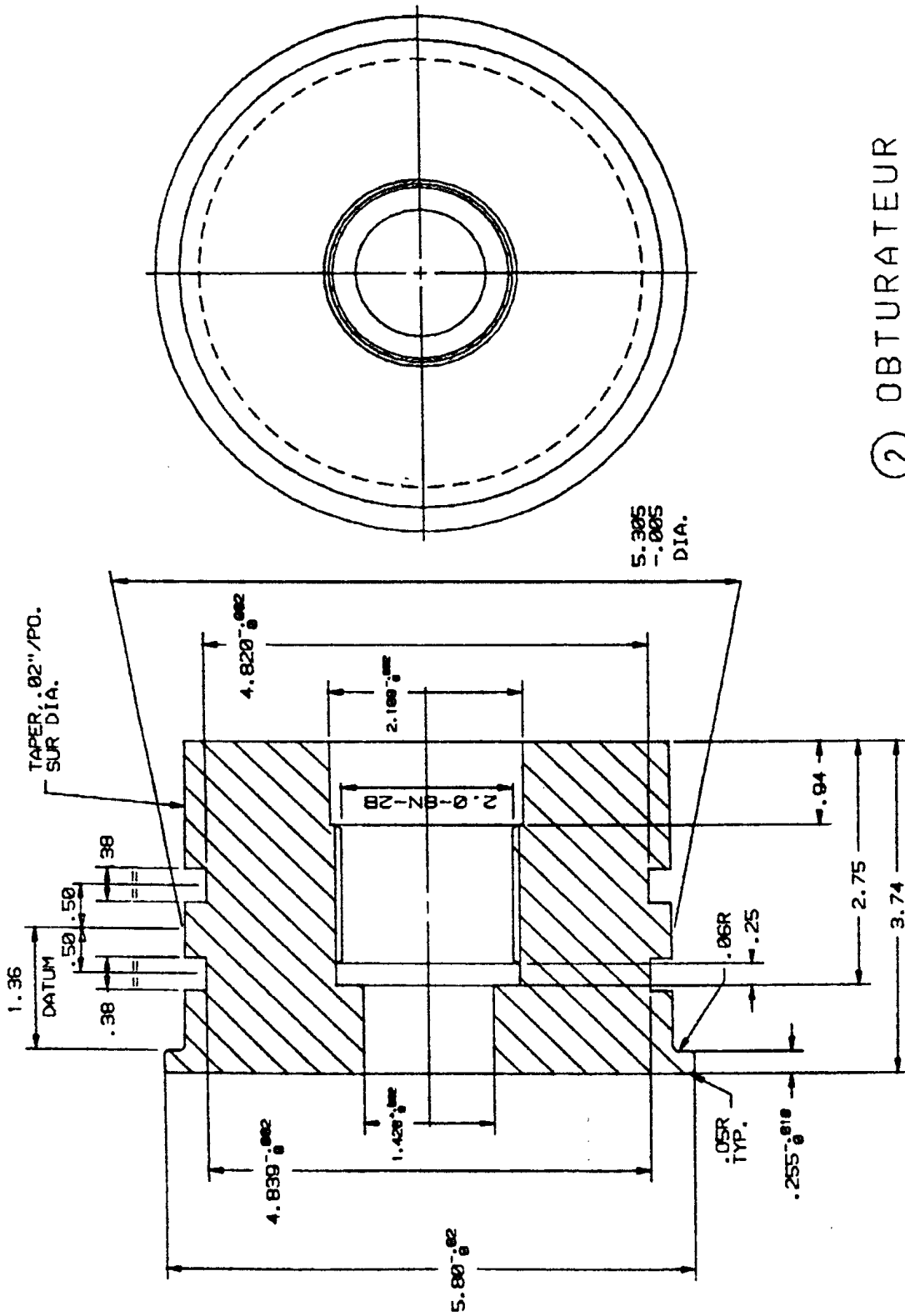
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- ① M-63 PRIMER
- ② OBTURATEUR
- ③ "O"RING 4.75IDx1/4
- ④ ARBRE
- ⑤ DIFFUSEUR
- ⑥ "O"RING 4.5IDx1/4
- ⑦ NOIX

ADAPTEUR HI/LO
CANON 110 MM SB

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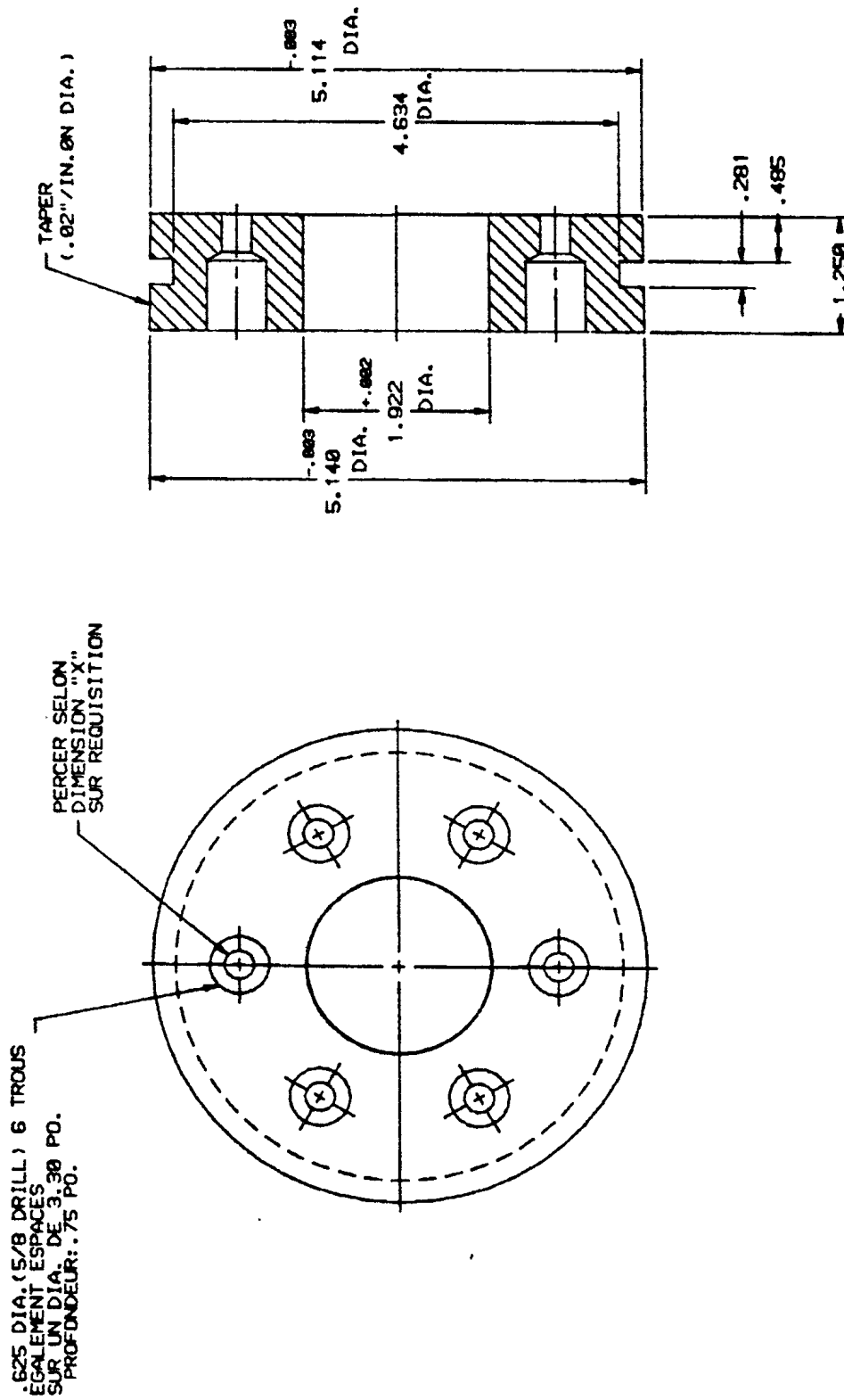


② OBTURATEUR

MAT: ACIER AISI 4340

TRAITER&DURCIR ROC"C"37-40

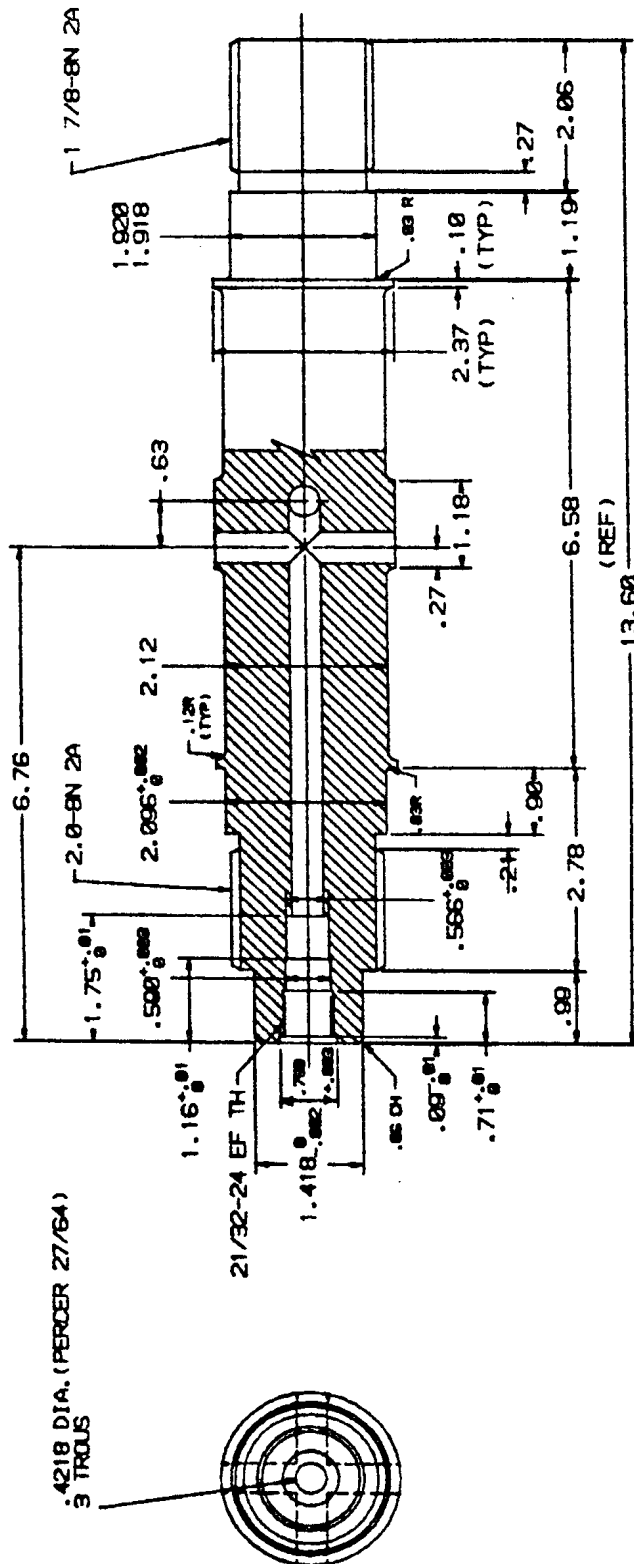
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⑤ DIFFUSEUR

MAT: AISI 4340 TRAITER ET DURCIR
ROC "C" 42-45

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④ ARBRE

MAT:ACIER AISI 4340
TRAITER,DURCIR ROC"C"37-40

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4. AUTHORS (Last name, first name, middle initial. If military, show rank, e.g. Doe, Maj. John E.)

DUPUIS, A.D., NORMAND, M.

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Preliminary free-flight tests were conducted to verify the integrity of sabots and scaled models of the MK-82 CF, and full-scale MPB - HD (BDU-5003/B) and MPB - LD (BDU-5002/B MOD 1) bombs launched from a powdered gun in the velocity range of 200 to 550 m/s. Two projectiles of each configuration were fired as well as a series of slugs for charge determination. The propellant charge mass, muzzle velocity, maximum accelerations, chamber pressure and drag coefficient were determined for each shot when fired from a 110-mm smooth bore gun with a high-low pressure chamber adapter. The models launched at a muzzle velocity less than 375 m/s were fired successfully.

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MODULAR PRACTICE BOMB
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BOMBS
MK-82 GPLD
GUN LAUNCHED
CHARGE DETERMINATION
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SUBSONIC
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